Extended Independent Comparison of Popular Deep Packet Inspection (DPI) Tools for Traffic Classification

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Abstract

Network traffic classification became an essential input for many network-related tasks. However, the continuous evolution of the Internet applications and their techniques to avoid being detected (as dynamic port numbers, encryption, or protocol obfuscation) considerably complicated their classification. We start the report by introducing and shortly describing several well-known DPI tools, which later will be evaluated: *PACE*, *OpenDPI*, *L7-filter*, *NDPI*, *Libprotoident*, and *NBAR*. We tried to use the most recent versions of the classifiers. However, OpenDPI project was closed in June 2011 and since that time no new version of this software was released. L7-filter, which is broadly described in the scientific literature, also seems to be not developed any longer – the most recent version of the classification engine is from January 2011 and the classification rules from 2009.

This report has several major contributions. At first, by using VBS, we created 3 datasets of 17 application protocols, 19 applications (also various configurations of the same application), and 34 web services, which are available to the research community. The first dataset contains full flows with entire packets, the second dataset contains truncated packets (the Ethernet frames were overwritten by 0s after the 70th byte), and the third dataset contains truncated flows (we took only 10 first packets for each flow). The datasets contain 767 690 flows labeled on a multidimensional level. The included application protocols are: DNS, HTTP, ICMP, IMAP (STARTTLS and TLS), NETBIOS (name service and session service), SAMBA, NTP, POP3 (plain and TLS), RTMP, SMTP (plain and TLS), SOCKSv5, SSH, and Webdav. The included applications (and their configurations) are: 4Shared, America's Army, BitTorrent clients (using plain and encrypted BitTorrent protocol), Dropbox, eDonkey clients (using plain and obfuscated eDonkey protocol), Freenet, FTP clients (in active and passive modes), iTunes, League of Legends, Pando Media Booster, PPLive, PPStream, RDP clients, Skype (including audio conversations, file transfers, video conversations), Sopcast, Spotify, Steam, TOR, and World of Warcraft. The included web services are: 4Shared, Amazon, Apple, Ask, Bing, Blogspot, CNN, Craigslist, Cyworld, Doubleclick, eBay, Facebook, Go.com, Google, Instagram, Justin.tv, LinkedIn, Mediafire, MSN, Myspace, Pinterest, Putlocker, QQ.com, Taobao, The Huffington Post, Tumblr, Twitter, Vimeo, VK.com, Wikipedia, Windows Live, Wordpress, Yahoo, and YouTube.

These datasets are available as a bunch of PCAP files containing full flows including the packet payload, together with corresponding text files, which describe the flows in the order as they were originally captured and stored in the PCAP files. The description files contain the start and end timestamps of flows based on the opening and closing of the system sockets, which is useful to reproduce the original behavior, when many short flows are generated between the same hosts during a short period of time. The application name taken from the system sockets is appended as well. Furthermore, each flow is described by one or more labels defining the application protocol, application itself, or the web service. These datasets can be directly used to test various traffic classifiers: port-based, DPI, statistical, etc.

At second, we developed a method for labeling non-HTTP flows, which belong to web services (as YouTube). Labeling based on the corresponding domain names taken from the HTTP header could allow to identify only the HTTP flows. Other flows (as encrypted SSL / HTTPS flows, RTMP flows) are left unlabeled. Therefore, we implemented a heuristic method for detection of non-HTTP flows, which belong to the specific services.

Then, we examined the ability of the DPI tools to accurately label the flows included in our datasets. All the classifiers except NBAR were tested by a special benchmark tool, which read the PCAP files together with their descriptions, composed the packets in the original flows, and provided the flows to the DPIs organized as libraries. To test the accuracy of NBAR, we needed to emulate a Cisco router by using Dynamips together with an original Cisco Internetwork Operating System image. The packets needed to be replayed back to the virtual interface where the Cisco router resided in order to be classified by NBAR. That imposed a few new

requirements. At first, the destination MAC address of each packet needed to be changed to the MAC address of the virtual Cisco router interface, as Cisco routers do not accept packets, which are not directed to their interfaces. At second, the source MAC addresses were changed to contain the identifiers of the original flows, so the router could re-construct and assess the flows as they were originated. Then, the Flexible NetFlow feature of Cisco routers was used to apply per-flow application label by NBAR. The NetFlow records were captured on the host machine, where they were analyzed.

It was shown that the detection rate is almost identical on the set containing full flows with entire packets and the set with truncated flows, while it highly decreases on the set with truncated packets. However, Libprotoident is an exception, as it provides the same results independent of the set, as it uses only 4 B of packet payload. We showed that, in most cases NBAR (apart of Libprotoident) was the most resistant tool regarding the impact of packet truncation on the detection rate.

We showed that PACE is able to identify the highest number of various web services among all the studied classifiers. PACE detected 16 web services, OpenDPI 2, L7-filter in its default version only 1, NDPI 7, Libprotoident 1, and NBAR none. We have also shown that L7-filter is characterized by a very high number of misclassified flows belonging to web services (usually 80–99 %) – the flows were recognized in a vast majority as *Finger* and *Skype*.

We evaluated the impact of protocol encryption or obfuscation on the detection rate by the particular classifiers. Protocol encryption made the detection rate lower in all the cases, while we did not see such dependency while using obfuscated eDonkey protocol – in this case, PACE demonstrated even increased detection rate from 16.50 % (for plain traffic) to 36 %. We have shown that only PACE is able to identify accurately some applications, which are supposed to be hard to detect, as Freenet or TOR.

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Barcelona, January 2014
Tomasz Bujlow, Valentin Carela-Español, and Pere Barlet-Ros

[1] See http://ec.europa.eu/regional_policy/thefunds/regional/index_en.cfm
[2] See http://www.bredbaandnord.dk/

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Chapter 1

Introduction

1.1 Overview

Classification of traffic in computer networks is a very challenging task. Many different types of tools were developed for that purpose. The first generation of tools used port-based classification [1, 2]. This fast technique is supported on most platforms, but its accuracy decreased dramatically during time, because of increasing share of protocols, which use dynamic port numbers. This concern especially Peer-to-Peer (P2P) applications, as eMule or BitTorrent [3–5]. Furthermore, some of applications on purpose use different port numbers than the standard one – this approach allow them to cheat port-based classifiers and obtain higher bandwidth, or higher priority in the network.

Because of the drawbacks of the port-based tools, a new technique called Deep Packet Inspection (DPI) was introduced. Because it relies on inspecting of the real payload [6], it is not possible to cheat the classifier by using non-standard port numbers. Apart from this big advantage, DPI also has many drawbacks. First of all, it cannot be used in many countries because of the local law. Second, even, if it is legal, it is often not used due to many privacy issues [3]. Third, it requires significant amount of processing power [3,4]. Finally, in some cases DPI is not possible because of used encryption techniques, or because the application or protocol changed its signature [3].

The third generation of network classification tools are statistical-based tools, which use various Machine Learning Algorithms (MLAs). They do not inspect the payload, but they rely on the behavior of the traffic (as packet sizes and their distribution, or time-based parameters). Sometimes other network or transport layer parameters are also included, as port numbers or DSCP. Because of this simplicity, MLAs can offer high accuracy compared to DPI tools (it is claimed to be over 95 %), while preserving low resource demands [1–3, 5–9].

To test the accuracy of any classification tool, we need to have a set of data of a good quality. Some datasets are available to the public (for example Caida sets [10]). Unfortunately, they do not contain all the data – often they miss the real payload, transport layer information, IP addresses, or inter-arrival times of the packets. Thanks to that, their usefulness in the development and testing of the classification tools is limited. Moreover, the datasets are already pre-classified by some tools; either port-based tools, or DPI tools. Even if they contain the original payload, we are not able to build the testing dataset based on the provided sets, because in order to do that, we would need to pre-classify them by some other classification tool.

To overcome that problem, we decided to build the dataset used for testing by ourselves. For this purpose, we used a tool developed at Aalborg University, called *Volunteer-Based System (VBS)*. Windows, Linux, and source versions of this tool were published under *GNU General Public License v3.0* and they are available as a SourceForge project [11]. The task of the project is to collect flows of Internet traffic data together with detailed information about each packet. For each flow we also collect the process name associated with it

from the system sockets. Additionally, the system collects some information about types of transferred HTTP contents. The design of the *Volunteer-Based System* was initially described in [12]. Further improvements and refinements can be found in [13]. We decided to use the system, since it was successfully used in many previous approaches [14–21]. The original *Volunteer-Based System* was modified by us in order to collect additionally the complete packets and some other information useful for data analysis.

In this report, we focus on two main tasks. The first task is to build a dataset, which will be useful for the testing purposes. The built dataset consists of PCAP files, which contain the real packets ordered by their timestamp and the information files, which describe each flow in details. The flow start and end time is provided, the process name associated with that flow, and some information which were extracted to make the analysis easier (as IP addresses, ports, associated types of HTTP content, etc). The dataset will be available to the public, so that other researchers can test their classifiers and compare their accuracy to the results obtained by us. The second part of the report focuses on testing different DPI tools. For that purpose, we chose Ipoque's Protocol and Application Classification Engine (PACE), OpenDPI, L7-filter, NDPI, Libprotoident, and Cisco NBAR. While testing the performance of different classification tools, we took into account three main parameters: accuracy, coverage (what amount of cases were left unclassified), and granularity (how detailed the classification is).

The remainder of this report is structured as follows. The rest of this chapter introduces the related work and the DPI tools used in our comparison. Then, in Chapter 2, we start by describing how we select the data for building the dataset used for testing. In Chapter 3, we show how we build our dataset. Afterwards, in Chapter 4, we present the methodology of testing different classification tools, while in Chapter 5, the obtained results are shown and discussed. Chapter 6 finalizes the report. Appendix A, Appendix B, and Appendix C provide the detailed results for all the classification sets.

1.2 Related Work

This section reviews the literature related to the main issues addressed in this work, namely the evaluation of DPI tools and the ground-truth for traffic classification.

1.2.1 Evaluation of DPI Tools

This section reviews the literature related to the comparison of DPI tools.

The OpenDPI tool amounts for most of the publications [22–26]. According to [22], the test performed by the European Networking Tester Center (EANTC) in 2009 resulted in 99 % of detection and accuracy for popular P2P protocols by OpenDPI. The big amount of flows marked as *unknown* by OpenDPI was confirmed in [23], where the authors made an effort to calculate various parameters for traffic originated from different applications: number of flows, data volume, flow sizes, number of concurrent flows, and inter-arrival times. The study was based on 3.297 TB of packets collected during 14 days from an access network with connected around 600 households. 80.1 % of the flows, amounting for 64 % of the traffic volume, were marked as *unknown* by OpenDPI.

In [22], the authors study the impact of per-packet payload sampling (i.e., packet truncation) and per-flow packet sampling (i.e., collect only the first packets of a flow) on the performance of OpenDPI. The results show that OpenDPI is able to keep the accuracy higher than 90-99% with only the first 4-10 packets of a flow. The impact by the per-packet payload sampling is considerably higher. Their results use as ground-truth the dataset labeled by OpenDPI with no sampling. Thus, the actual classification of the dataset is unknown and no possible comparison with our work can be done.

Similar work, performed by the same authors, is described in [25]. The goal was to find out what is the suggested number of packets from each flow, which needs to be inspected by OpenDPI in order to achieve good accuracy, while maintaining a low computational cost. The focus was on Peer-to-Peer (P2P) protocols. The test was performed on a 3 GB randomly selected subset of flows from the data collected at an access link

of an institution over 3 days. The authors found that inspecting only 10 packets from each flow lowered the classification abilities of P2P flows by OpenDPI by just 0.85 % comparing to the classification of full flows, while saving more than 9 % of time.

In [24], the authors tested the accuracy of L7-filter and OpenDPI, and they also built their own version of L7-filter with enhanced abilities of classification of the UDP traffic. The data used in the experiment were collected by Wireshark, while the applications were running in the background. The data were split into 27 traces, each for one application, where all the applications were supported by both L7-filter and OpenDPI. Other flows were removed from the dataset. However, they do not explain how they validate the process of the isolation of the different applications. The obtained precision was 100 % in all the cases (none of the classification tools gave a false positive), while the recall deviated from 67 % for the standard L7-filter, through 74 % for their own implementation of L7-filter, and 87 % for OpenDPI.

Fukuda compared in [27] the performance of L7-filter and OpenDPI on the backbone traffic. The dataset used is characterized as being in majority asymmetric and containing the packets truncated after 96 Bytes. The ground-truth is labeled using the port-based technique and then the three DPI-based techniques are compared. The results show that the DPI-based techniques are only able to classify 40-60% of the traffic in this scenario.

In [28], the developers of Libprotoident evaluated the accuracy of the classification of this tool and compared the results with OpenDPI, Nmap, and L7-filter. The ground-truth was established by PACE, so only the flows recognized by PACE were taken into account during the experiment. The accuracy was tested on two datasets: one taken from the Auckland university network, and one from an Internet Service Provider (ISP). On the first dataset, Libprotoident had the lowest error rate of less than 1 % (OpenDPI: 1.5 %, L7-filter: 12.3 %, Nmap: 48 %.). On the second dataset, Libprotoident achieved the error rate of 13.7 %, while OpenDPI 23.3 %, L7-filter 22 %, and Nmap 68.9 %. The authors claim that Libprotoident identified 65 % of BitTorrent traffic and nearly 100 % of HTTP, SMTP, and SSL. Same authors also compared in [29] four open-source DPI-based tools (i.e., NDPI, Tstat, Libprotoident, and L7-filter). Similarly to us, they artificially built a labeled dataset using a complicate mix of filters in an isolated host. Unlike us, their trace is not available to the community so no further comparison is possible. However, their results confirms some of the findings of our paper presenting NDPI and Libprotoident as the most accurate open-source DPI-based tools.

To the best of our knowledge, there are no accessible research studies or reports about the accuracy of NBAR. However, an experiment was made to assess how big amount of network traffic is classified by NBAR and L7-filter, and how big amount of traffic is left as *unknown* [30]. The authors captured by Wireshark all the packets flowing in a local network of an IT company during 1 hour. From 27 502 observed packets, 12.56 % were reported as unknown by NBAR, and 30.44 % were reported as unknown by L7-filter.

A very comprehensive review of different methods for traffic classification was made in 2013 by Silvio Valenti et al. [31]. The authors refer to 68 different positions in the literature and cover the topic from the basis to more advanced topics, mostly dealing with Machine Learning Algorithms (MLAs). The paper starts by enumerating various classification techniques (port-based, DPI, stochastic, statistical, and behavioral) and explaining which properties are exploited, what is the granularity, timeliness, and computational cost of these methods. The granularity of DPI was stated as *fine grained*, which means that DPI is not only able to distinguish between large family of protocols (P2P, HTTP, FTP), but it is also able to identify a particular application (as *eMule*). The result of DPI can be provided after inspecting the first payload to match a specific signature, so the computational cost of this method is moderate. Another payload-based method is Stochastic Packet Inspection (SPI), which relies on the statistical properties of the payload, needs to inspect a few packets in order to provide a result, and which characterizes by high computational cost [31].

In [32], it was introduced a method for validation of classification algorithms, which is independent of other classification methods, deterministic, and allows to automatize testing of large data sets. The authors developed a Windows XP driver based on the Network Driver Interface Specification (NDIS) library. Because of that, outgoing and incoming packets can be processed before leaving or entering the operating system. Outgoing packets, which fulfill the imposed requirements, are marked with the first two letters of the corre-

sponding application names obtained from the system. The tag is placed in the Router Alert IP option field, which is transparent both for the routers and for the end point host.

1.2.2 DPI for Ground-Truth Establishment

The paper by Dusi et al. [33] is, to the best of our knowledge, the only work similar to ours. However, there are other papers related to the evaluation of the DPI-based techniques used in this work.

Obtaining the ground-truth can be based on the already existing datasets. An example are Cooperative Association for Internet Data Analysis (CAIDA) data traces, which were collected in a passive or an active way [10]. Another example is the Internet Measurement Data Catalog [34], also operated by CAIDA, which provides the references to different sources of data traces, which are available for research. The data are not stored by CAIDA itself, but on external servers [35]. Although the datasets are pre-classified (or they claim to contain only the traffic from the particular application / protocol), we do not know how the sets were created and how clean they are, which is a very important factor during testing traffic classifiers. Also, most of them have no payload or just the first bytes of each packet. MAWI repository [36] contains various packet traces, including daily 15-minutes traces made at an trans-Pacific line (150 Mbit/s link). The traces contain the first 96 bytes of the payload and the traffic is usually asymmetric. Another useful data source is the Community Resource for Archiving Wireless Data At Dartmouth (CRAWDAD) [37], which stores wireless trace data from many contributing locations. Some interesting comparison studies were made using datasets from different providers. In [38] the authors compare the data obtained from CAIDA and CERNET [39]. Many significant differences between them were found and they concern the lifetimes, lengths, rates of the flows, and the distribution of the TCP and UDP ports among them. Another interesting project is The Waikato Internet Traffic Storage (WITS) [40], which aims to collect and document all the Internet traces that the WAND Network Research Group from the University of Waikato has in their possession. Some of the traces can be freely downloaded and they contain traffic traces from various areas and of different types (as DSL residential traffic, university campus traffic, etc). Most of the traces do not have payload (it is zeroed) or truncated.

A very interesting approach to obtain the ground-truth was taken in [41]. The authors created an application, which collects the data from the network and labels the flows with the real application names (as *Thunderbird*) and application protocol names (as *SMTP*). The application is built from several components. The first component is the client, which is available for various operating systems. It tracks down the active network sockets and sends to the server information about when the particular sockets were opened and closed. The second component, packet capture engine, can be deployed in any architecture, and its task is to capture the packets from the given point in the network, and to send the packets to the server. The server component merges the packets with the information obtained from the system sockets. Additionally, *L7-filter* based classifier inspects every flow to assign the proper application protocol. Another modification to enhance the tagging of short flows (persisting less than 200 ms, for which the corresponding sockets could not be noticed), was to copy the tag of the already tagged application, which shares the same flow information in a time interval. Thanks to that, the authors claim to tag 95 % of flows produced by hosts (30000 flows in total), which amount for more than 99 % of data volume. This tool is somehow similar to VBS, the tool used in this work for the ground-truth generation.

Another way of establishing the ground-truth was shown in [42], which is describing a system developed to accelerate the manual verification process. The authors proposed Ground Truth Verification System (GTVS) based on the DPI signatures derived from the databases available in the Internet, including L7-filter. The signatures were tested on hand-classified data, and the poor-quality signatures were improved. Additionally, heuristic mechanisms were added to improve the classification. The authors assumed that flows with the same end-points (IP addresses and ports) belong to the same application. Moreover, the host names (as *eBay*) were used to further refine the results during the iterative process. GTVS, however, does not collect the application names from the operating systems, so the established truth cannot be completely verified.

Table 1.1: DPI Tools Included in Our Comparison

Name	Version	Released	Apps. Identified
PACE	1.47.2	November 2013	1000
OpenDPI	1.3.0	June 2011	100
nDPI	rev. 6992	November 2013	170
L7-filter	2009.05.28	May 2009	110
Libprotoident	2.0.7	November 2013	250
NBAR	15.2(4)M2	November 2012	85

1.3 Classification Tools

On the market, there are many available software-based traffic classification solutions. For our experiment, we selected PACE, OpenDPI, NDPI, Libprotoident, NBAR, and L7-filter, which will be broadly introduced in this section. Table 1.1 summarizes these DPI-based tools along and their characteristics.

PACE. It is a proprietary classification library developed by *ipoque* entirely in C, which supports classical DPI (pattern matching), behavioral, heuristic, and statistical analysis. According to its website, PACE is able to detect encrypted protocols as well as protocols which use obfuscation. Overall, more than 1000 applications and 200 network protocols are supported. It is also possible to include user-defined rules for detection of applications and protocols. To the best of our knowledge, PACE is the only commercial tool used in the literature to build the ground truth [28]. For this reason we chose PACE as the representative of commercial DPI tools.

OpenDPI. It was an open-source classifier derived from early versions of PACE. Compared to the commercial version, OpenDPI removed support for encrypted protocols, as well as all performance optimizations. The project is now considered as closed. In [22, 25] the authors mention that OpenDPI is not a classic DPI tool, as it uses other techniques apart from pattern matching (i.e., behavioral and statistical analysis). Thanks to that, it should not provide false classification results, but some traffic can remain unclassified [22]. Another interesting feature of OpenDPI is flow association, which relies on inspecting the payload of a known flow to discover a new flow. An example can be inspecting a control FTP session to obtain the five tuple of the newly initiated data session [24].

NDPI. It is an OpenDPI fork, which is optimized and extended with new protocols – for now it supports more than 100 of them [43]. Support for many encrypted protocols was provided by analyzing session certificates. The architecture is scalable, but it does not provide the best performance and results: each of the protocols has its own signature scanner, through which the packets are examined. Every packet is examined by each scanner, regardless, if a match was found. If there are multiple matches per flow, the returned value is the most detailed one [24]. Additionally, there is no TCP or IP payload re-assembly, so there is no possibility to detect a signature split into multiple TCP segments / IP packets [43].

Libprotoident. This C library [28] introduces Lightweight Packet Inspection (LPI), which examines only the first four bytes of payload in each direction. That allows to minimize privacy concerns, while decreasing the disk space needed to store the packet traces necessary for the classification. Libprotoident supports over 200 different protocols and the classification is based on a combined approach using payload pattern matching, payload size, port numbers, and IP matching.

Cisco Network Based Application Recognition (NBAR). It was developed to add the ability to classify the network traffic by using the existing infrastructure [44]. It is able to the perform classification of applications which use dynamic TCP and UDP port numbers. NBAR works with Quality of Service (QoS)

features, thanks to what the devices (e.g., routers) can dynamically assign a certain amount of bandwidth to a particular application, drop packets, or mark them in a selected way. The authors claim that NBAR supports a wide range of stateful protocols, which are difficult to classify. There are 2 versions of NBAR in use: the standard NBAR and NBAR2, which is currently supported only on a very limited set of Cisco routers from 19xx, 29xx, and 39xx series [45], and on a few other devices: ISR-G2, ASR1K, ASA-CX and Wireless LAN Controller [46]. Therefore, our classification was limited to the standard NBAR, which is still under constant development, and which is included in most Cisco devices and in the newest IOS from line 15.x.

L7-filter. This DPI-based tool is probably the most popular technique used for ground-truth generation in the research literature. L7-filter was created in 2003 as a classifier tool for Linux Netfilter, being able to recognize the traffic on the application layer [47]. The classification is based on three techniques. At first, simple numerical identification based on the standard iptables modules, which can handle port numbers, IP protocol numbers, number of transferred bytes, etc. At second, payload pattern matching based on regular expressions. At third, the applications can be recognized based on functions. L7-filter is developed as a set of rules and a classification engine, which can be used independently of each other. The most recent version of L7-filter classification engine is from January, 2011, and the classification rules from 2009.

Chapter 2

Selection of the Data

The process of building a representative dataset, which characterizes a typical user behavior, is a challenging task, crucial from the point of testing and comparing different traffic classifiers. Therefore, to ensure the proper diversity and amount of the included data, we decided to combine the data on a multidimensional level. Based on w3schools statistics [48], we found that most PC users use Windows 7 (56.7 % of all users), Windows XP (12.4 % of all users), Windows 8 (9.9 % of all users), and Linux (4.9 %) – state for October 2013. Apple computers contribute for 9.6 % of the overall traffic, and mobile devices for 3.3 %. Because of the lack of the equipment as well as the necessary software for Apple computers and mobile devices as well as the low popularity of Windows 8 during the testing period, we decided to include Windows 7 (W7), Windows XP (XP), and Linux (LX), which cover now 74.0 % of the used operating systems.

The application protocols, applications, and web services selected by us are shown below:

2.1 File-Sharing Applications

According to the reports from Palo Alto [49], they amount for 6 % of the total bandwidth. Inside that group BitTorrent amounts for 53 %, FTP for 21 %, Dropbox for 5 %, Xunlei for 4 %, and eMule for 3 %. The following applications were selected based on the report from Palo Alto Networks, CNET [50] and OPSWAT P2P clients popularity list, CNET FTP clients popularity list [51], and Direct Download popularity list [52].

- BitTorrent: uTorrent (Windows), kTorrent (Linux). We tested the Torrent protocol clients by downloading few files of different size and then leaving the files to be seeded for some time in order to obtain enough of traffic in both directions. Peer-to-peer applications generate a big number flows per a file and, therefore, the number of files used in the experiment is sufficient. We studied the following configurations:

  a) All connections encrypted

  b) All incoming connections accepted (encrypted and non-encrypted), but outgoing connections non-encrypted

  The links to the Torrent files were originated:

  a) Among the most common downloads from a website with legal torrents ClearBits [53] (3 files):
     - *Episode One S01E01* (1169 MB)
     - *pearl-jam-life-wasted-video* (29.6 MB)
     - *Sick of Sarah - 2205 BitTorrent Edition* (49.2 MB)

b) From the official Ubuntu website (1 Ubuntu image):
   - *ubuntu-13.10-desktop-amd64.iso* (883 MB)

- eDonkey: eMule (Windows), aMule (Linux). We studied the following configurations:

  a) All connections obfuscated
  b) All incoming connections accepted (obfuscated and non-obfuscated), but outgoing connections non-obfuscated

  The eDonkey protocol clients were tested on 5 large files (Ubuntu images, around 800 MB each), which were every time searched in the internal search engine of each eDonkey protocol client:

  - *kubuntu-13.04-desktop-amd64.iso*
  - *kubuntu-13.10-desktop-amd64.iso*
  - *ubuntu-13.04-desktop-amd64.iso*
  - *ubuntu-13.04-desktop-i386.iso*
  - *ubuntu-13.10-desktop-amd64.iso*

- FTP: FileZilla (Windows, Linux). We studied the following configurations:

  a) Active mode (PORT)
  b) Passive mode (PASV)

  The following operations were performed:

  - Upload one directory with 29 pictures (50 MB)
  - Upload one big ZIP file (50 MB)
  - Browse the directory tree
  - Download again the directory with 29 pictures
  - Delete the directory from the server
  - Download again the big ZIP file
  - Delete the big ZIP file from the server

- Dropbox (Windows, Linux). The following operations were performed:

  - Upload one directory with 29 pictures (50 MB)
  - Upload one big ZIP file (50 MB)
  - Synchronize the Dropbox folder with another computer, to which the content is downloaded
  - Delete the content of the Dropbox folder from the other computer

- Web-based direct downloads: 4Shared (including Windows application), MediaFire, Putlocker

- Webdav (Windows). The following operations were performed:

  - Upload one directory with 29 pictures (50 MB)
  - Browse the directory tree
  - Download again some pictures
  - Delete the directory from the server
  - Create some folders and delete them

2.2 Photo-Video Group

According to the reports from Palo Alto [49], they amount for 16 % of the total bandwidth, where YouTube amounts for 6 % of total, Netflix for 2 % of total, other HTTP video for 2 % of total, RTMP for 2 % of total, and others for 4 % of traffic in total. We also used Ebizmba ranking of video websites [54].

- YouTube. The watched videos are the most watched videos from all the times according to the global ranking [55]. The operations performed on YouTube:
  - Watch the 10 most popular videos (global ranking)
  - Make some comments
  - Click randomly *Like* or *Not like*
  - Try to pause some random videos from the list and then resume them
  - Try to rewind forward or backward some random videos from the list
- Netflix. The following operations were performed: watch quick fragments of around 10 different movies, sometimes scrolling forward or backward, browse the categories
- Other HTTP video. It is done automatically while browsing various websites. No further action is needed
- RTMP: Around 30 random short live video streams (1–10 minutes) were watched from Justin.tv
- Vimeo – a web-based photo sharing solution
- PPStream (Windows) – P2P streaming video software

2.3 Web Browsing Traffic

Based on w3schools statistics [56], the most popular web browsers are: Chrome (48.4 % of all users), Firefox (30.2 % of all users), and Internet Explorer (14.3 % of all users). These browsers were used to generate the traffic. According to the reports from Palo Alto [49], they amount for 20 % of the total bandwidth. The selection of the websites was based on Alexa statistics [57], Ebizmba web statistics [58], Quantcast statistics [59], and Ebizmba search engines popularity [60]. In order to make the dataset as representative as possible, we simulated different human behaviors when using these websites. The visited websites were:

- Google

  For each term from the top 10 searched terms on Google [61]:
  - Browse the first 10 search results. This should give us more realistic traffic in out set, since users tend to browse websites which are on the top of results from search engines
  - Browse Google Images associated with that term
  - Go to Google Maps and try to look for places associated with that term. Then, select one random place and zoom until the Street View appears. Afterwards, turn around until all the 360 degrees view from Street View is downloaded
- Yahoo
  - Login to the service

  - Search for something, see various images, photo galleries, and videos
  - Browse news, including videos and photo galleries
  - Autos
  - Games
  - Horoscopes
  - Jobs
  - Mail: read messages, sent messages/replies without attachment, send one message with few pictures attached
  - Movies
  - Music
  - Shopping
  - Sports
  - Travel
  - Weather
  - Download few files from Yahoo Downloads

- Facebook
  - Join some Facebook groups (1–5)
  - Post on the group
  - Like some posts on the group
  - Add some comments to someone's comments on the group
  - Invite some friends
  - Accept invitation from other friends
  - Browse pictures of Enrique Iglesias
  - Add some personal details to the profile
  - Like some pages (10–20)
  - Posts on a page which you like
  - Like some posts on a page which you like
  - Comment some posts on a page which you like
  - Share some photos from pages which you like
  - Attend few events
  - Invite friends to that events
  - Accept invitation for events from other friends
  - Share some events on the wall
  - Create an event
  - Invite friends for the event created by ourselves
  - Make some posts and likes on the page of our event
  - Post something on our wall

  - Like some posts on other people wall
  - Comment some posts on other people wall
  - Upload 29 pictures (60 MB)
  - Browse the pictures which we uploaded
  - Browse a page called *My Afghanistan Best At All*
  - Watch some videos on the page *My Afghanistan Best At All*

- Twitter
  - Register an account
  - Upload the profile picture, complete the profile with random data
  - Edit the profile
  - Follow some people
  - Write some tweets
  - Retweet some tweets
  - Comment under some tweets
  - Search

- Wikipedia

  The watched sites are the 10 most searched terms in Wikipedia for each language [62]:
  - English
  - Dutch
  - German
  - Spanish
  - Japanese

- MSN

  We browsed various sub-pages in different categories: pictures, videos, news, sport, weather, etc

- Amazon
  - Search for 5 random products
  - Follow the links from each website to other sub-pages
  - Try to optimize search by adding various conditions
  - Read the terms and conditions, informational pages, etc

- eBay
  - Search for 5 random products
  - Follow the links from each website to other sub-pages
  - Try to optimize search by adding various conditions
  - Read the terms and conditions, informational pages, etc

- Tumblr
  - Register an account
  - Upload the profile picture, complete the profile with random data
  - Edit the profile
  - Search
  - Communicate with some people
  - Comment some blogs
- Google+
  - Register an account
  - Upload the profile picture, complete the profile with random data
  - Edit the profile
  - Search
  - Add random people to random circles
  - Add some posts
  - Comment some posts of other users
  - Upload random pictures
- Pinterest
  - Register an account
  - Upload the profile picture, complete the profile with random data
  - Edit the profile
  - Search
  - Communicate with some people
  - Add some ranodm stuff as *pins*
  - Create some categories
- LinkedIn
  - Register an account
  - Upload the profile picture, complete the profile with random data
  - Edit the profile, add job experience, education, etc
  - Search for different people and companies
  - Try to establish some contacts with people
  - Browse the jobs
- MySpace
  - Register an account
  - Upload the profile picture, complete the profile with random data

  - Edit the profile
  - Search
  - Play various music
  - Add music to favorites

- Cyworld
- VK.com
- QQ.com
- Windows Live
- Taobao
- Blogspot
- Craigslist.org
- Go.com
- CNN Interactive
- WordPress.com
- The Huffington Post
- Instagram
- Apple
- Bing search engine
- Ask search engine
- Doubleclick

2.4 Encrypted Tunnel Traffic

According to the reports from Palo Alto [49], they amount for 9 % of the total bandwidth, where 6 % of total is SSL and 2 % of total is SSH.

- SSL (Windows, Linux). These flows are collected fully automatically while using various applications and web services
- SSH (Linux)
- TOR (Windows). We tested TOR in 2 ways. At first, we used the TOR browser to browse various websites and download some big files. Then, we configured TOR to act as an internal relay, so we participated in creating the invisible path for other users
- Freenet (Windows). We connected to Freenet network and established relationships with 85 peers. We searched for various content and browsed various websites located in Freenet, downloaded some files from them. We configured Freenet to act as a relay for other peers as well

- SOCKSv5 (Windows). We created a SOCKSv5 server on the Linux machine, which tunneled all requests to and from the Internet. Then, we used Firefox on the Windows machine to connect to the Linux machine by SOCKSv5. The SOCKS traffic from Firefox from the Windows machine was captured. We browsed various websites and downloaded some files to simulate normal Firefox activity

2.5 Storage-Backup Traffic

According to the reports from Palo Alto [49], they amount for 16 % of the total bandwidth, where at least half of the bandwidth is consumed by MS-SMB, and the rest by many different applications.

- MS-SMB (Windows, Linux). The following operations were performed:
  - Upload one directory with 29 pictures (50 MB)
  - Upload 3 big ZIP files (50 MB each)
  - Browse the directory tree
  - Create some directories on the server
  - Move some files between the directories
  - Delete some directories
  - Download again the directory with 29 pictures
  - Delete the directory from the server
  - Download again the 3 big ZIP files
  - Delete the big ZIP files from the server

2.6 E-mail and Communication Traffic

According to the reports from Palo Alto [49], e-mail traffic amounts for 3 % of the total bandwidth. E-mail market share from October 2013 [63] shows that only one desktop mail client, Microsoft Outlook (17 %), is in the top 10 of used mail clients. The rest is split between web-based clients (as GMail) and mobile clients (Mac, Android). The tested applications / web-based mail services include: Gmail, Hotmail, Windows Live Mail (Windows), and Mozilla Thunderbird (Windows). The desktop e-mail applications (Windows Live Mail and Mozilla Thunderbird) were tested to use various protocols:

a) SMTP-PLAIN (port 587)

b) SMTP-TLS (port 465)

c) POP3-PLAIN (port 110)

d) POP3-TLS (port 995)

e) IMAP-STARTTLS (port 143)

f) IMAP-TLS (port 993)

We also tested Skype between Windows and Android OS: video sessions, voice conversations, and file transfers.

2.7 Management Traffic

This type of traffic is common by nature in each network. It includes DNS, ICMP, NETBIOS, NTP, and RDP.

2.8 Games

Based on DFC Intelligence the most played online games in USA [64], we selected the following games:

- League of Legends (Windows) – including all launchers
- World of Warcraft (Windows) – including all launchers
- Pando Media Booster (Windows) – a process added by League of Legends to seed the game installer to other users, which offloads the servers, because the download is performed in the P2P mode. It generates enormous amounts of traffic and fills the connection
- Steam – it delivers a range of games straight to a computer's desktop. Includes automatic updates, lists of games and prices, posters, plus access to a large number of games. We included Steam on the list as it is a platform for numerous games and it generates a lot of traffic
- America's Army – one of the most popular games from Steam

2.9 Others

This category includes:

- Spotify (Windows)
- iTunes (Windows)
- PPLive (Windows) – a P2P Internet TV
- Sopcast (Windows) – a P2P Internet TV

Chapter 3

Building the Dataset

Testing different network traffic classifiers involved a number of various tasks. At first, the dataset used for testing had to be build. That required installing necessary machines in desired configurations (operating systems, applications, etc) and equipping them in a data collecting software. To collect the traffic, we decided to use a modified version of the Volunteer-Based System developed at Aalborg University. Thanks to it we could collect all the packets passing the network interfaces, where the packets are grouped into flows, and the process name taken from the system sockets is assigned to each flow.

3.1 Our Testbed

Because of the difficulty of accessing the real hardware, we decided to create our testing environment as a mixture of hardware and virtual machines. The hardware machines were used as our data generating stations and equipped with Windows 7 (2 stations) and Ubuntu (2 stations). We also installed 3 virtual machines as our data generating stations and we equipped them with Windows 7, Windows XP, and Ubuntu. Additionally, we installed a virtual server machine, equipped with a MySQL database, for data storage. All the virtual machines were accessible by Remote Desktop, which allowed us to capture the traffic of this activity as well. The Linux machines were also accessible by SSH.

To collect and accurately label the flows, we adapted the Volunteer-Based System (VBS) for Research on the Internet developed at Aalborg University [13]. The task of the VBS project is to collect the information about the flows of Internet traffic data (i.e., start time of the flow, number of packets contained by the flow, local and remote IP addresses, local and remote ports, transport layer protocol) together with the detailed information about each packet (i.e., direction, size, TCP flags, and relative timestamp to the previous packet in the flow). For each flow, the system also collects the process name associated with that flow. The process name is obtained from the system sockets. Because of this we can ensure the application associated to a specific traffic. Additionally, the system collects some information about the types of transferred HTTP contents (e.g., *text/html*, *video/x-flv*). The captured information is transmitted to the VBS server, which stores the data in a MySQL database. The design of VBS was initially described in [12]. Further improvements and refinements can be found in [13]. We decided to use the system, since it was successfully used in many previous approaches [14–19].

On every data generating station, we installed a modified version of Aalborg University Volunteer-Based System for Research on the Internet. The source code of the original system as well as the modified version was published under *GNU General Public License v3.0* and it is available in GIT repository in the SourceForge project [11]. The modified version of the system differs from the original one by several things:

- The client saves full captured frames as payloads

- Each packet with an HTTP header is stored together with the corresponding URL and referrer
- The server stores the payloads and the new information in the database
- The client does not intercept the communication between the client and the server to prevent intercepting the traffic generated by itself
- We increased the limit of the size of the database on the client side when the database is sent to the server
- We decreased the size of the flow / number of packets in the memory before the packets are dumped to the local database
- We changed the IP address in the client configuration file in order to make the connection from the new clients to the new server
- The server has increased RAM availability in the YAJSW config file
- The IP addresses are stored in non-hashed version in the database
- The performance statistics are not generated
- The real timestamps are stored instead of relative timestamps to make easier ordering of the packets
- Provider network names are not supported
- We added a module called *pcapBuilder*, which is responsible for dumping all the flows to PCAP files. At the same time, INFO files are generated to provide detailed information about each flow, which allows to assign each packet in the PCAP file to the individual flow
- We added a module called *logAnalyzer*, which is responsible for analyzing logs generated by different DPI tools, and assigning the results of the classification to the flows in the database

The simplified topology of our testbed with the installed components of VBS (seven clients and one server) is shown in Fig. 3.1.

3.2 Labeling the Data

All the flows captured by VBS and stored in the database needed to be properly marked by attaching to them the labels of applications, application protocols, web services, types of the content, or Internet domains. One flow can be associated with multiple labels. Flows, which are not labeled, will not be taken into consideration in the final dataset.

3.2.1 Consistency Checks

Before the labeling begins, all the flows are checked for consistency and the damaged flows are repaired or removed from the database. At first, we delete all TCP flows with truncated start. Such flows could be captured while VBS was starting up, so the flows were captured from a specific time point. It is also possible that 2 or more flows were merged into one by our VBS if they were originated from and to the same endpoints (the same local and remote IP addresses, ports, and the same transport protocol) and the socket was closed and opened during so short interval that could not be noticed by VBS. Therefore, the TCP flows are examined for three-way handshakes and split accordingly into multiple flows. At the end, we delete empty flows, which contain only packets with SYN, FIN, and RST flags.

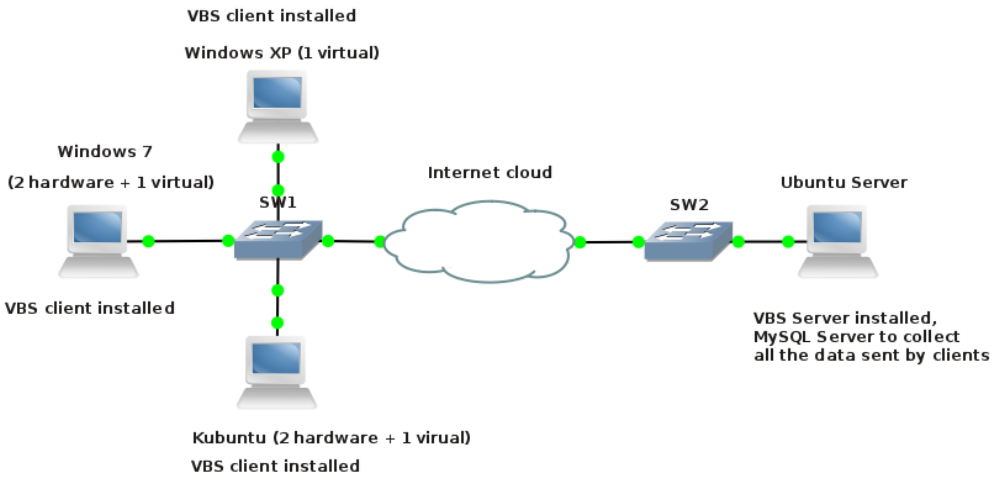

Figure 3.1: Topology of our testbed

3.2.2 Application Protocols

The application protocol label is applied only to these flows, which we are sure that transmit the specific application protocol. The following application protocols were identified by us:

- DNS: the application names is *svchost* or *dnsmasq* and the remote port is 53
- HTTP: the flows must have at least one packet, which contains the URL field in HTTP header or the content-type field in HTTP header
- ICMP: the protocol name must be ICMP
- IMAP-STARTTLS: the application name is *wlmail* or *thunderbird*, the remote port is 143
- IMAP-TLS: the application name is *wlmail* or *thunderbird*, the remote port is 993
- NETBIOS Name Service: the application name is *system* or *smbd*, the local or remote port is 137
- NETBIOS Session Service: the application name is *system* or *smbd*, the local or remote port is 139
- SAMBA Session Service: the application name is *system* or *smbd*, the local or remote port is 445
- NTP: the application name is *ntpd* or *svchost*, the local and remote ports are 123, the protocol name is UDP, the flow does not carry HTTP
- POP3-PLAIN: the application name is *wlmail* or *thunderbird*, the remote port is 110
- POP3-TLS: the application name is *wlmail* or *thunderbird*, the remote port is 995
- RTMP: the application name is *chrome* or *firefox* or *iexplore* or *plugin-contai**, the flow does not carry HTTP, the remote IP is 199.9.* or 188.125.94.* or 188.125.95.*, the remote port is 1935
- SMTP-PLAIN: the application name is *wlmail* or *thunderbird*, the remote port is 587
- SMTP-TLS: the application name is *wlmail* or *thunderbird*, the remote port is 465

- SOCKSv5: the remote IP is 147.83.42.154, the remote port is 6666
- SSH: the application name is *sshd* or *sshd:*, the flow does not carry HTTP
- Webdav: the application name is *svchost*, the remote IP is 79.99.7.149

3.2.3 Applications

The application label tells nothing about the protocol used by the application, as for example, a web-browser can use many different protocols, a BitTorrent client can connect to websites to download files using HTTP or SSL, etc. This level of labeling is used when we were not able to distinguish different protocols used by the same application based on the information from VBS. The following applications were identified by us:

- 4Shared: flows created by 4Shared, a direct download application. Conditions: the application name is *desktop*
- America's Army: flows created by America's Army first-shooter game. It also contains integrated Teamspeak for voice conversations. Conditions: the application name is *aa3loader* or *aa3game*
- BitTorrent clients (encrypted): flows from BitTorrent application, encryption is used for all of the flows using BitTorrent protocol. Other protocols used by the application (as HTTP, SSL, DNS) are allowed as well. Conditions: the application name is *utorrent* or *ktorrent**, the start timestamp > 1382529600000000
- BitTorrent clients (non-encrypted): flows from BitTorrent application, encryption is not used for the outgoing flows using BitTorrent protocol, but encrypted incoming flows are accepted. Other protocols used by the application (as HTTP, SSL, DNS) are allowed as well. Conditions: the application name is *utorrent* or *ktorrent**, the start timestamp < 1382529600000000
- Dropbox: flows generated by Dropbox. Conditions: the application name is *dropbox*
- eDonkey clients (obfuscated): flows from eDonkey clients, obfuscation is used for all of the flows using eDonkey protocol. Other protocols used by the application (as HTTP, SSL, DNS) are allowed as well. Conditions: the application name is *emule* or *amule*, the start timestamp > 1382529600000000
- eDonkey clients (non-obfuscated): flows from eDonkey clients, obfuscation is not used for the outgoing flows using eDonkey protocol, but obfuscated incoming flows are accepted. Other protocols used by the application (as HTTP, SSL, DNS) are allowed as well. Conditions: the application name is *emule* or *amule*, the start timestamp < 1382529600000000
- Freenet: flows generated by Freenet. Conditions: the application name is *java*, the local IP is 172.26.12.32, the local port is 16070, the start timestamp >= 1383599499949738 and <= 1383601015833089
- FTP clients (active): flows from FTP client operating in the active mode (PORT). Other protocols than FTP used by the application (as HTTP, SSL) are allowed as well. Conditions: the application name is *filezilla*, the start timestamp < 1382529600000000
- FTP clients (passive): flows from FTP client operating in the passive mode (PASV). Other protocols than FTP used by the application (as HTTP, SSL) are allowed as well. Conditions: the application name is *filezilla*, the start timestamp > 1382529600000000
- iTunes: flows from iTunes. Conditions: the application name is *itunes*
- League of Legends: flows from League of Legends game. Conditions: the application name is *lolclient* or *league of legends* or *lollauncher* or *rads_user_kernel*

- Pando Media Booster: flows from Pando Media Booster. Conditions: the application name is *pmb*
- PPLive: flows from PPLive. Conditions: the application name is *ppap* or *pplive*
- PPStream: flows from PPStream. Conditions: the application name is *ppskernel*
- RDP clients: flows generated by Remote Desktop applications. Other protocols than RDP used by the application (as SSL) are allowed as well. Conditions: the application name is *svchost* or *xrdp*, the local port is 3389, the flow does not transmit HTTP
- Skype: flows generated by Skype application. They can contain exchange of users' directory, voice calls, video conversations, file transfers, HTTP and SSL flows with advertisements, etc. Conditions: the application name is *skype*
- Sopcast: flows belonging to Sopcast application. Conditions: the application name is *sopcast*
- Spotify: flows belonging to Spotify application. Conditions: the application name is *spotify*
- Steam: flows belonging to Steam application. Conditions: the application name is *steam*
- TOR: flows belonging to TOR application. Conditions: the application name is *tor*
- World of Warcraft: flows belonging to World of Warcraft application. Conditions: the application name is *blizzard launcher* or *wow* or *world of warcraft launcher* or *agent*

3.2.4 Web Services

Every web service is identified by a set of domains, which to this server belong. The domains were chosen based on the number of their occurrences in the collected HTTP flows. We identified the following web services and the associated domains:

- 4Shared: *.4shared.com
- Amazon: amazon.com, amazonaws.com, amazon-adsystem.com
- Apple: apple.com
- Ask: *.ask.com
- Bing: *.bing.com, *.bing.net
- Blogspot: *.blogspot.*
- CNN: *.cnn.com, *.cnn.co, *.cnn.c, *.cnn.net
- Craigslist: *.craigslist.*
- Cyworld: *.cyworld.*
- Doubleclick: *.doubleclick.net
- eBay: *.ebay.com, *.ebaystatic.com, *.ebaydesc.com, *.ebayrtm.com
- Facebook: facebook.*, fbcdn.net
- Go.com: *.go.*

- Google: google.*, googleads.*, google-analytics.*, googlesyndication.*, googleusercontent.*, googleadservices.*, googletagservices.*, gstatic.com
- Instagram: instagram.com
- Justin.tv: justin.tv, justintvlivefs.*, jtvnw.net
- LinkedIn: *.linkedin.com
- Mediafire: *.mediafire.com
- MSN: msn.com
- MySpace: *.myspacecdn.com
- Pinterest: *.pinterest.com
- Putlocker: *.putlocker.com, *.putlockerdownloader.com
- QQ.com: qq.com
- Taobao: *.taobao.com, *.taobaocdn.com
- The Huffington Post: *.huffingtonpost.com, *.huffpost.com
- Tumblr: tumblr.com
- Twitter: twitter.*, twimg.com
- Vimeo: vimeo.com, *.vimeocdn.com
- VK.com: vk.com, *.vk.*
- Wikipedia: wikipedia.*, wikimedia.*, mediawiki.*, wikimediafoundation.*
- Windows Live: *.live.com
- Wordpress: wordpress.com
- Yahoo: yahoo.*, yimg.com, yahooapis.*
- YouTube: youtube.*, ytimg.com, youtube-nocookie.*

The HTTP flows are marked with the web services labels if they contain only the traffic from the matching domains. In case, if the flow contains traffic from domains belonging to multiple services (or domains, which are not assigned to the selected by us services), the flow is left as unlabeled. The HTTP flows are also marked with the labels of the type of the transmitted content, if they transmit audio or video. However, this method allows us to label only HTTP flows, while the other flows (as SSL) belonging to the web services are still unlabeled. Therefore, we implemented a heuristic method for detection of non-HTTP flows, which belong to the specific services. To be recognized as a non-HTTP web flow, the application name associated with the flow should be the name of the web browser (as *chrome*), a name of a web browser plugin (as *plugin-container*, *flashgcplay*), or the name should be missing. Then, we look at the HTTP flows, which were originated from 2 minutes before to 2 minutes after the non-HTTP web flow. If all the corresponding (originated from the same local machine and reaching the same remote host) HTTP flows have a web service label assigned, and the service label is the same for all of the flows, the non-HTTP flow obtains the same web service label.

3.3 The Final Dataset

Our basic dataset (without truncated packets or flows) contains 767 690 flows, which account for 53.31 GB of pure packet data. The application name was present for 759 720 flows (98.96 % of all the flows), which account for 51.93 GB (97.41 %) of the data volume. The remaining flows are unlabeled due to their short lifetime (usually below 1 s), which made VBS incapable to reliably establish the corresponding sockets. The application protocols together with the number of flows and the data volume are shown in Table 3.1, while the applications in Table 3.2 and the web services in Table 3.3.

Table 3.1: Application Protocols in the Dataset

Protocol	Number of Flows	Number of Megabytes
DNS	18251	7.66
HTTP	43127	7325.44
ICMP	205	2.34
IMAP-STARTTLS	35	36.56
IMAP-TLS	103	410.23
NETBIOS Name Service	10199	11.13
NETBIOS Session Service	11	0.01
SAMBA Session Service	42808	450.39
NTP	42227	6.12
POP3-PLAIN	26	189.25
POP3-TLS	101	147.68
RTMP	378	2353.67
SMTP-PLAIN	67	62.27
SMTP-TLS	52	3.37
SOCKSv5	1927	898.31
SSH	38961	844.87
Webdav	57	59.91

Table 3.2: Applications in the Dataset

Application	Number of Flows	Number of Megabytes
4Shared	144	13.39
America's Army	350	61.15
BitTorrent clients (encrypted)	96399	3313.98
BitTorrent clients (non-encrypted)	261527	6779.95
Dropbox	93	128.66
eDonkey clients (obfuscated)	12835	8178.74
eDonkey clients (non-obfuscated)	13852	8480.48
Freenet	135	538.28
FTP clients (active)	126	341.17
FTP clients (passive)	122	270.46
iTunes	235	75.4
League of Legends	23	124.14
Pando Media Booster	13453	13.3
PPLive	1510	83.86
PPStream	1141	390.4
RDP clients	153837	13257.65
Skype (all)	2177	102.99
Skype (audio)	7	4.85
Skype (file transfer)	6	25.74
Skype (video)	7	41.16
Sopcast	424	109.34
Spotify	178	195.15
Steam	1205	255.84
TOR	185	47.14
World of Warcraft	22	1.98

Table 3.3: Web Services in the Dataset

Web Service	Number of Flows	Number of Megabytes
4Shared	98	68.42
Amazon	602	51.02
Apple	477	90.22
Ask	171	1.86
Bing	456	36.84
Blogspot	235	10.53
CNN	247	3.66
Craigslist	179	4.09
Cyworld	332	13.06
Doubleclick	1989	11.24
eBay	281	8.31
Facebook	6953	747.35
Go.com	335	25.83
Google	6541	532.54
Instagram	9	0.22
Justin.tv	2326	126.33
LinkedIn	62	2.14
Mediafire	472	27.99
MSN	928	23.22
Myspace	2	2.54
Pinterest	189	3.64
Putlocker	103	71.92
QQ.com	753	10.46
Taobao	387	24.29
The Huffington Post	71	21.19
Tumblr	403	52.56
Twitter	1138	13.67
Vimeo	131	204.45
Vk.com	343	9.59
Wikipedia	6092	521.95
Windows Live	26	0.16
Wordpress	169	33.31
Yahoo	17373	937.07
YouTube	2534	1891.79

We are going to publish our basic labeled dataset with full packet payloads on our website [65]. Therefore, it can be used by the research community as a reference benchmark for the validation of network traffic classifiers.

Chapter 4

Testing the Classifiers

The process of testing different DPI tools is complex and, therefore, we split it into several parts: building the PCAP files, the classification process, and analysis of the classification logs. Some of the steps can be different for some DPIs than for the others – in these cases the differences are explicitly highlighted.

4.1 Building the PCAP Files

The labeled data stored in the database must be extracted in a particular format, which will be handled by the DPI tools. Each tool can have different requirements and possibilities, so the extracting tool must handle all these issues. The most challenging thing is to instruct the DPIs, how to construct flows in the identical way as they were constructed by VBS, which creates and closes flows based on opening or closing of the system sockets. DPI tools do not have such information, so the time of the start and end of each flow must be explicitly provided to them. The data are extracted into PCAP files, which contain all packets ordered according to their absolute timestamps, so that the packets are provided to the classifiers in the original order. Some classifiers can rely on the flow coexistence feature (many flows from the same IP address), or use DNS requests to obtain the names of the particular services. Extracting of the packets was automatized by our *pcapBuilder* tool, which is a part of the modified VBS system.

The packets were extracted in 3 different modes, which will be studied in detail:

1. The normal one
2. Truncated packets (Ethernet frames were overwritten by 0s after the 70th byte)
3. Truncated flows (we extracted only 10 first packets for each flow)

4.1.1 PACE, OpenDPI, L7-filter, NDPI, and Libprotoident

The PCAP files provided to PACE, OpenDPI, L7-filter, NDPI, and Libprotoident, are accompanied by INFO files, which contain the information about the start and end of each flow, together with the flow identifier. Because of that, the software, which uses the DPI libraries, is able to create and terminate the flows in the appropriate way, as well as to provide the classification results together with the flow identifier.

To generate the input for PACE, OpenDPI, L7-filter, NDPI, and Libprotoident we can use the following syntax of our *pcapBuilder* tool:

a) `java -jar pcapBuilder.jar --writeDefault` – the normal mode

b) `java -jar pcapBuilder.jar --writeDefaultTruncatePackets` – truncated packets mode (Ethernet frames were overwritten by 0s after the 70th byte)

c) `java -jar pcapBuilder.jar --writeDefaultTruncateFlows` – truncated flows mode (we extracted only 10 first packets for each flow)

In each case, a set of 2 files is generated:

- A PCAP file, which contains all the flows. The packets are ordered by their absolute timestamps
- An INFO file, which contains the description of the flows. Based on the descriptions, the classifiers are able to construct the flows in the same manner as they were constructed by our system

The format of each row in the INFO file is as follows:

```
flow_id + "#" + start_time + "#" + end_time + "#" + local_ip + "#" + remote_ip + "#"
    + local_port + "#" + remote_port + "#" + transport_protocol + "#" + operating_system
    + "#" + process_name + "#" + labels + "#-#-#"
```

4.1.2 NBAR

Preparing the data for NBAR classification is more complicated. There are no separate INFO files describing the flows, since the classification is made directly on the router. The default behavior of NBAR – terminating the flows after a timeout – does not work in our case as well. At first, flows created in that way do not match 1:1 the flows built by VBS. At second, we were replaying the packets to the router with the maximal possible speed, so many different flows would be merged. Therefore, we needed to extract the packets in a way, which will allow them to be processed by the router and to be correctly grouped into flows. We achieved that by changing both the source and destination MAC addresses during the extraction process. The destination MAC address of every packet must match up with the MAC address of the interface of the router (set by us to be *ca:00:11:5b:00:00*), because the router cannot process any packet which is not directed to its interface on the MAC layer. The source MAC address was set up to contain the identifier of the flow to which it belongs, so the flows were recognized by the router according to our demands.

To generate the PCAP files for NBAR, our *pcapBuilder* tool can be used – it required the destination MAC address of the Cisco router as a parameter:

a) `java -jar pcapBuilder.jar --writeNBAR ca:00:11:5b:00:00` – the normal mode

b) `java -jar pcapBuilder.jar --writeNBARTruncatePackets ca:00:11:5b:00:00` – truncated packets mode (Ethernet frames were overwritten by 0s after the 70th byte)

c) `java -jar pcapBuilder.jar --writeNBARTruncateFlows ca:00:11:5b:00:00` – truncated flows mode (we extracted only 10 first packets for each flow)

4.2 The Classification Process

4.2.1 Versions of L7-filter

In the classification, we used several versions of L7-filter:

a) L7-filter-all

It is the standard version with all the patterns activated, but the patterns marked as *overmatching* have a low priority.

b) L7-filter-sel

It is the standard version, the patterns marked as *overmatching* are deactivated.

c) L7-filter-com

At UPC, we also developed a version of L7-filter, which was used to process the biggest possible amount of traffic in the accurate way. The modifications for that version are described in our Computer Networks journal paper [66]:

- The patterns are applied from the least overmatching to the most overmatching
- Packets must agree with the rules given by pattern creators – otherwise, the packet is not labeled
- In case of multiple matches, the flow is labeled with the application given by the rule with the highest quality according to L7-filter documentation. In case if the quality of many patterns is equal, the first label matched is chosen

d) L7-filter-aut

At UPC, we also developed another version of L7-filter, which was used for our automatic retraining mechanism [67]. This version does not have activated the patterns declared as *overmatching* and it has some patterns manually made by us to match the traffic from YouTube, Twitter, and Facebook. The priorities given to our patterns allowed to classify by these patterns the biggest possible amount of traffic.

4.2.2 PACE, OpenDPI, and L7-filter-aut

At UPC, we designed a tool called *dpi_benchmark*, which is able to read the PCAP files and provide the packets one-by-one to the relevant DPI classifiers. After the last packet of the flow is sent to the classifier, the tool is obtaining the classification label associated with that flow. The labels are written to the log files together with the flow identifier, which makes us later able to relate the classification results to the original flows in the database. To see all possible options of the classification we can run:

```
./dpi_benchmark -help
```

To process the set of PCAP and INFO files by the classifiers we execute the following command:

```
./dpi_benchmark -f path/to/pcap/file -b path/to/info/file > output/file
```

The format of each row in the log files is:

```
id#initial_ts#final_ts#src_ip#dst_ip#src_port#dst_port#OS#process_name#original_labels
   #-#-#PACE_label#OpenDPI_label#L7_filter_label#unused#unused#
```

The last two labels will not be considered, since they belong to our internal implementation of a statistical classification tool, which is not properly trained.

4.2.3 L7-filter-all, L7-filter-sel, and L7-filter-com

The *dpi_benchmark* tool also has three versions, which support the other versions of L7-filter. The tools work as the tool described in the previous section – they read the PCAP files and provide the packets one-by-one to L7-filter. After the last packet of the flow is sent to the classifier, the tool is obtaining the classification label associated with that flow. The labels are written to the log files together with the flow identifier, which makes us later able to relate the classification results to the original flows in the database. To see all possible

options of the classification we can run:

```
./dpi_benchmark -help
```

To process the set of PCAP and INFO files by the classifiers we execute the following command:

```
./dpi_benchmark -f path/to/pcap/file -b path/to/info/file > output/file
```

The format of each row in the log files is:

```
id#initial_ts#final_ts#src_ip#dst_ip#src_port#dst_port#OS#process_name#original_labels
   #-#-#L7_filter_label#
```

4.2.4 NDPI

The *dpi_benchmark* tool also has a version, which supports NDPI classifier. It works as the tools described in the previous section – it reads the PCAP files and provides the packets one-by-one to NDPI. After the last packet of the flow is sent to the classifier, the tool is obtaining the classification label associated with that flow. The labels are written to the log files together with the flow identifier, which makes us later able to relate the classification results to the original flows in the database. To see all possible options of the classification we can run:

```
./dpi_benchmark -help
```

To process the set of PCAP and INFO files by the classifiers we execute the following command:

```
./dpi_benchmark -f path/to/pcap/file -b path/to/info/file > output/file
```

The format of each row in the log files is:

```
id#initial_ts#final_ts#src_ip#dst_ip#src_port#dst_port#OS#process_name#original_labels
   #-#-#NDPI_label#
```

4.2.5 Libprotoident

The *dpi_benchmark* tool also has a version, which supports Libprotoident. It works as the tools described in the previous section – it reads the PCAP files and provides the packets one-by-one to Libprotoident. After the last packet of the flow is sent to the classifier, the tool is obtaining the classification label associated with that flow. The labels are written to the log files together with the flow identifier, which makes us later able to relate the classification results to the original flows in the database. To see all possible options of the classification we can run:

```
./dpi_benchmark -help
```

To process the set of PCAP and INFO files by the classifiers we execute the following command:

```
./dpi_benchmark -f path/to/pcap/file -b path/to/info/file > output/file
```

The format of each row in the log files is:

```
id#initial_ts#final_ts#src_ip#dst_ip#src_port#dst_port#OS#process_name#original_labels
   #-#-#Libprotoident_label#
```

4.2.6 NBAR

Choice of the Proper NBAR Version

There are 2 versions of NBAR in use: the casual NBAR and NBAR2. Unfortunately, NBAR2 is currently supported only on a very limited set of Cisco devices:

- Routers from 19xx, 29xx, and 39xx series [45]
- Other devices: ISR-G2, ASR1K, ASA-CX and Wireless LAN Controller [46]

So, the classification will be limited to the standard NBAR, which is still under constant development and which is included in most of Cisco devices and in the newest IOS from line 15.x.

Choice of the Cisco Device and the Operating System IOS

We did not have any free Cisco device which we can use for the experiment. However, we could use GNS3 – a graphical framework, which uses Dynamips to emulate Cisco hardware. The following Cisco platforms of routers can be emulated by Dynamips / GNS3:

- 1710, 1720, 1721, 1750, 1751, 1760
- 2610, 2611, 2610XM, 2620, 2620XM and 2650XM, 2611XM, 2621, 2621XM and 2651XM, 2691
- 3620, 3640, 3660
- 3725, 3745
- 7206

We chose the 7200 platform, since only for this platform there is available the newest version of Cisco IOS (version 15), which contains Flexible NetFlow. Previous versions of Cisco IOS contain only traditional NetFlow, which do not support NBAR reporting on per flow basis. According to the Cisco Feature Navigator, the newest IOS for the 7200 platform, which contains interesting to us features, is:

```
Release:  15.2(4)M2
Platform:  7200
Feature set:  ADVANCED ENTERPRISE SERVICES
DRAM: 512
Flash:  64
Image:  c7200-adventerprisek9-mz.152-4.M2.bin
```

The set of the interesting features contained by the image is shown in Figure 4.1. We downloaded the IOS image from one of our routers, which are used in production, and used the image with GNS3. The router identifies itself as *Cisco IOS Software, 7200 Software (C7200-ADVENTERPRISEK9-M), Version 15.2(4)M2, RELEASE SOFTWARE (fc2)* – for the full listing see Figure 4.2.

```
NBAR - Citrix ICA Published Applications
NBAR - Multiple Matches Per Port
NBAR - Network-based Application Recognition
NBAR Extended Inspection for HTTP Traffic
NBAR PDLM Versioning
NBAR Real-time Transport Protocol Payload Classification
NBAR Static IPv4 IANA Protocols
NBAR User-Defined Custom Application Classification
NBAR- BitTorrent PDLM
NBAR-NAT Integration & RTSP
Flexible NetFlow
Flexible NetFlow - Ingress VRF Support
Flexible NetFlow - Output Features on Data Export
Flexible NetFlow: 32 bit AS Number Support
Flexible Netflow - IPv4 Multicast Statistics Support
Flexible Netflow - Layer 2 Fields
Flexible Netflow - MPLS Egress NetFlow
Flexible Netflow - NBAR Application Recognition
Flexible Netflow - NetflowV5 export protocol
Flexible Netflow - Top N Talkers Support
```

Figure 4.1: The interesting features contained by the IOS image

Connection of the Router to the Real Network

In order to connect the router to the real network, we needed to create a virtual interface on our Linux machine (*tap0*) and bridge it creating a new virtual bridge interface (*br0*). First of all, it is worth to highlight that the way of connecting the device to the computer without using bridge (but only *tap0* interface) does not work. Such way is described on many websites, but it is evidently just a copy-paste without checking if such approach works or not. At first, we create a virtual *Internet cloud* interface *tap0* and we bridge it to *br0*. Then, we set all the parameters of the bridge, as the IP address:

```
modprobe tun
tunctl -t tap0
ifconfig tap0 0.0.0.0 promisc up
brctl addbr br0
brctl addif br0 tap0
ifconfig br0 10.0.0.2 netmask 255.255.255.0 up
ifconfig tap0 mtu 65521
ifconfig br0 mtu 65521
```

If necessary, we can add any other interface to the bridge – for example to connect the router to the Internet:

```
ifconfig eth0 0.0.0.0 promisc up
brctl addif br0 eth0
```

or to connect to a VMWare virtual machine:

```
ifconfig vmnet1 0.0.0.0 promisc up
brctl addif br0 vmnet1
```

Deleting the interfaces is going in the opposite way:

```
brctl delif br0 tap0
ifconfig br0 down
```

```
Cisco IOS Software, 7200 Software (C7200-ADVENTERPRISEK9-M), Version 15.2(4)M2, RELEASE SOFTWARE (fc2)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2012 by Cisco Systems, Inc.
Compiled Wed 07-Nov-12 18:15 by prod_rel_team

ROM: ROMMON Emulation Microcode
BOOTLDR: 7200 Software (C7200-ADVENTERPRISEK9-M), Version 15.2(4)M2, RELEASE SOFTWARE (fc2)

ROUTER0 uptime is 8 hours, 56 minutes
System returned to ROM by unknown reload cause - suspect boot_data[BOOT_COUNT] 0x0, BOOT_COUNT 0, BOOTDATA
      19
System image file is "tftp://255.255.255.255/unknown"
Last reload reason: unknown reload cause - suspect boot_data[BOOT_COUNT] 0x0, BOOT_COUNT 0, BOOTDATA 19

This product contains cryptographic features and is subject to United States
...

If you require further assistance please contact us by sending email to
export@cisco.com.

Cisco 7206VXR (NPE400) processor (revision A) with 245760K/16384K bytes of memory.
Processor board ID 4279256517
R7000 CPU at 150MHz, Implementation 39, Rev 2.1, 256KB L2 Cache
6 slot VXR midplane, Version 2.1

Last reset from power-on

PCI bus mb0_mb1 (Slots 0, 1, 3 and 5) has a capacity of 600 bandwidth points
Current configuration on bus mb0_mb1 has a total of 200 bandwidth points.
This configuration is within the PCI bus capacity and is supported.

PCI bus mb2 (Slots 2, 4, 6) has a capacity of 600 bandwidth points.
Current configuration on bus mb2 has a total of 0 bandwidth points
This configuration is within the PCI bus capacity and is supported.

Please refer to the following document "Cisco 7200 Series Port Adaptor
Hardware Configuration Guidelines" on Cisco.com <http://www.cisco.com>
for c7200 bandwidth points oversubscription and usage guidelines.

1 FastEthernet interface
125K bytes of NVRAM.

65536K bytes of ATA PCMCIA card at slot 0 (Sector size 512 bytes).
8192K bytes of Flash internal SIMM (Sector size 256K).

Configuration register is 0x2102
```

Figure 4.2: The identification of the router by *show version* command

```
brctl delbr br0
tunctl -d tap0
```

On the router side, we connect the *Fastethernet0/0* interface to the *tap0* interface of the Internet cloud.

Configuration of the Router

We configure the router to enable Flexible NetFlow with NBAR on the *Fastethernet0/0* interface. NetFlow records will be sent back to the Linux machine, where they will be stored and processed later. We also set a static MAC address on the interface, since every time the router is started, the "physical" MAC address is different. To connect to the router, we use *telnet*:

```
tomasz@kubuntu: $ telnet localhost 2001
Trying ::1...
```

```
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
Connected to Dynamips VM "R1" (ID 0, type c7200) - Console port
Press ENTER to get the prompt.
```

Now, we are going to present how the router was configured. The particular steps were shown and discussed in the following points:

a) General configuration

We want to setup the router name to be more friendly. The router should by default discard all the packets, which enter the interface, without performing any routing:

```
hostname ROUTER0
ip route 0.0.0.0 0.0.0.0 Null0
```

b) Configuration of the flow record

The router must be instructed how to group the packets into flows (the *match* command), and which information for each flow should be collected (the *collect* command):

```
flow record nbar-appmon
-> description NBAR flow monitor
-> match ipv4 protocol
-> match ipv4 source address
-> match ipv4 destination address
-> match transport source-port
-> match transport destination-port
-> match datalink mac source address input
-> collect counter bytes
-> collect counter packets
-> collect application name
```

c) Configuration of the flow exporter

The router must be instructed where the flows should be exported and which option tables should be included in the export. The option tables allows to match the identifiers of the NBAR classes to be matched to the actual names:

```
flow exporter export-to-computer
-> description flexible NF v9
-> destination 10.0.0.2
-> source FastEthernet0/0
-> transport udp 9995
-> template data timeout 60
-> option interface-table
-> option exporter-stats
-> option vrf-table
-> option application-table
-> option application-attributes
```

d) Configuration of the flow monitor

The configured flow record must be associated with the configured flow exporter:

```
flow monitor application-mon
-> description app traffic analysis
-> exporter export-to-computer
-> cache timeout active 60
-> record nbar-appmon
```

e) Configuration of the interface

Every time GNS3 start, another MAC address is assigned to the interface. Because we need a fixed value (to be able to replay the packets to the interface), we assign a static one. Then, we need to enable NBAR on the interface and apply the created flow monitor:

```
interface FastEthernet0/0
-> mac-address ca00.115b.0000
-> ip address 10.0.0.1 255.255.255.0
-> ip nbar protocol-discovery
-> ip flow monitor application-mon input
-> duplex full
```

Configuration of the Linux Computer

Computers running Linux can be tweaked to replay the packets to the network in an enhanced way. The following is known to apply to the 2.4.x and 2.6.x series of kernels. By default Linux's *tcpreplay* performance isn't all that stellar. However, with a simple tweak, relatively decent performance can be had on the right hardware. By default, Linux specifies a 64 K buffer for sending packets. Increasing this buffer to about half a megabyte does a good job:

```
echo 524287 >/proc/sys/net/core/wmem_default
echo 524287 >/proc/sys/net/core/wmem_max
echo 524287 >/proc/sys/net/core/rmem_max
echo 524287 >/proc/sys/net/core/rmem_default
```

Replaying the Packets to the Router

We can send the packets to the router using the bridge interface:

```
tcpreplay -i br0 --pps=3000 packets_nbar_1.pcap
tcpreplay -i br0 --pps=3000 packets_nbar_2.pcap
tcpreplay -i br0 --pps=3000 packets_nbar_3.pcap
```

To obtain the results, we needed to setup the NetFlow analyzer on the computer while the PCAP file was being replayed. It is worth mentioning that it is required to specify the speed with which the packets are replayed. Without specifying the speed, the packets would be replayed with the same speed as they were captured. It means that for our 2-months capture we would need to have the same 2-months replay period. The speed of replaying can be specified in packets per second or Megabytes per second. It is much better to use the first possibility, since the latter one cause enormous number of small packets sent during a short interval of time. This overloads the router and causes input queue drops. To adjust the number of packets per second which we are able to replay, we used the interface counter – no drops should be observed during the replay. To see that, we used the *show interfaces* command on the router, and we observed the *input drops* parameter:

```
ROUTER0#show flow monitor application-mon cache format table
  Cache type:                               Normal
  Cache size:                                 4096
  Current entries:                             140
  High Watermark:                              140

  Flows added:                                 381
  Flows aged:                                  241
    - Active timeout      (    60 secs)          0
    - Inactive timeout    (    15 secs)        241
    - Event aged                                 0
    - Watermark aged                             0
    - Emergency aged                             0

IPV4 SRC ADDR    IPV4 DST ADDR   SRCP  DSTP   PROT  app name
==============  ==============  =====  =====  ====  ==================
192.168.1.128   91.189.92.163   38126     80     6  port http
192.168.1.128   173.194.41.228  56856     80     6  cisco unclassified
173.194.41.228  192.168.1.128      80  56856     6  cisco unclassified
192.168.1.128   173.194.41.230  46235    443     6  port secure-http
173.194.41.230  192.168.1.128     443  46235     6  port secure-http
74.125.235.111  192.168.1.128      80  49617     6  cisco unclassified
192.168.1.128   91.189.90.143   56001   6969     6  cisco bittorrent
192.168.1.128   87.216.1.66         0    771     1  prot icmp
```

Figure 4.3: The flow monitor cache

```
ROUTER0#show interfaces fastEthernet 0/0
FastEthernet0/0 is up, line protocol is up
...
Input queue:  0/75/0/0 (size/max/drops/flushes);
...
```

On the router side, we can see that the flows are properly inspected and that the Flexible NetFlow entries are generated as expected. We can see that looking into the temporary cache of the router by *show flow monitor application-mon cache format table* (see Figure 4.3). To display the mappings between the application names and IDs, we can use the *show flow exporter option application table* command (see Figure 4.4).

Receiving the NetFlow Records by the Linux Computer

There are many approaches to collect the NetFlow v9 records. Unfortunately, most of the tools, which are supposed to work with NetFlow v9, do not support that format entirely. It means that either only some basic fields are supported, or the tools are not working at all if any custom field is added. This especially concerns field #95 – the application identifier. It took us around 3 weeks of experimenting with many different tools to find a one which is working properly with NetFlow v9 exports! Here there are some experiences with the tools (free and commercial) which are supposed to support NetFlow v9 format:

a) NFDUMP

The standard tool NFDUMP [68] can collect only the standard fields from the NetFlow exports and it does not allow to collect any additional features, for example, the application name. However, we tested, if any NetFlow exports are collected at all. We started the capturing tool by:

```
nfcapd -p 9995 -b 10.0.0.2 -T all -t 61 -l /home/tomasz/nfcapd
```

Then, we processed the NetFlow records to obtain a human-readable version:

```
ROUTER0#show flow exporter option application table

Engine: prot (IANA_L3_STANDARD, ID: 1)

appID  Name                      Description
-----  ----                      -----------
1:8    egp                       Exterior Gateway Protocol
1:47   gre                       General Routing Encapsulation
1:1    icmp                      Internet Control Message Protocol
1:88   eigrp                     Enhanced Interior Gateway Routing Protocol
...

Engine: port (IANA_L4_STANDARD, ID: 3)

appID  Name                      Description
-----  ----                      -----------
3:21   ftp                       File Transfer Protocol
3:80   http                      World Wide Web traffic
3:179  bgp                       Border Gateway Protocol
...
3:25   smtp                      Simple Mail Transfer Protocol
3:53   dns                       Domain Name System

Engine: NBAR (NBAR_CUSTOM, ID: 6)

appID  Name                      Description
-----  ----                      -----------
6:244  custom-10                 Custom protocol custom-10
6:245  custom-09                 Custom protocol custom-09
...

Engine: cisco (CISCO_L7_GLOBAL, ID: 13)

appID  Name                      Description
-----  ----                      -----------
13:0    unclassified              Unclassified traffic
13:1    unknown                   Unknown application
13:9    ipsec                     IP Security Protocol (ESP/AH)
13:12   cuseeme                   CU-SeeMe desktop video conference
13:13   dhcp                      Dynamic Host Configuration Protocol
13:26   netbios                   Netbios
...
13:59   kazaa2                    Kazaa Version 2
13:554  rtsp                      Real Time Streaming Protocol
13:61   rtp                       Real Time Protocol
13:62   mgcp                      Media Gateway Control Protocol
13:63   skinny                    Skinny Call Control Protocol
13:64   h323                      H323 Protocol
13:66   rtcp                      Real Time Control Protocol
13:67   edonkey                   eDonkey
13:68   winmx                     WinMx file-sharing application
13:69   bittorrent                bittorrent
13:70   directconnect             Direct Connect Version 2.0
13:83   skype                     Skype Peer-to-Peer Internet Telephony
13:84   sap                       SAP Systems Applications Product in Data
...
```

Figure 4.4: Applications recognized by NBAR together with their IDs

```
nfdump -o raw -R /home/tomasz/nfcapd
```

We confirmed that the NetFlow exports are correct, but as expected, we did not obtain the application names. To see that everything is exported from the router as expected, we used the standard TCPDUMP tool:

```
tcpdump -i br0 -n 'src 10.0.0.1 and udp and dst port 9995' -w /home/tomasz/tcpdump.out
```

In case of problems, if any background process is occupying a port and we need to know the name of the process, it is sufficient to invoke the following command to obtain the application PID:

```
netstat -tulpn | grep 9995
```

where 9995 is the port number we want to inspect.

b) PMACCT

This set of PMACCT tools [69] is very powerful and it supports as well NetFlow v9 export format as field #95 (application name). However, to be able to capture flow records, all the records must contain packet counters and byte counters – without that, the flow records are ignored. We used the following command to obtain the relevant statistics:

```
nfacctd -L 10.0.0.2 -l 9995 -r 30 -c src_mac,src_host,dst_host,proto,src_port,dst_port,
   class -P print -O csv > nbar_results.txt
```

There is also a theoretical possibility to put the configuration in a file:

```
nfacctd_ip:  10.0.0.2
nfacctd_port:  9995
plugins:  print[test]
!
aggregate[test]:  src_mac,src_host,dst_host,proto,src_port,dst_port,class
print_refresh_time[test]:  30
print_output[test]:  csv
print_output_file[test]:  /home/tomasz/nbar_results.txt
```

Afterwards, we can execute nfacctd as:

```
nfacctd -f nfacctd.cfg
```

For now this way is not working properly, since every 30 seconds the file is completely overwritten with the new data (instead of just appending the data to the file) and there is no possibility to override this behavior.

This tool is the only tool tested by us, which works with NetFlow v9 format including field #95 as it should! Therefore, we chose PMACCT to collect the NetFlow data from the router. The data collection process must be done in the following way:

- Start the NetFlow collector (*nfacctd*) on the computer
- Wait until at least one flow entry with other class than *unknown* appears in the log file. This is necessary since the collector must obtain from the router some special *option tables* before it will be able to recognize what is the application class. Before it happens, all the flows will be marked as *unknown*. No traffic generation is required during this step. Router generates multicasts by itself and they will be included in the log. This step can take even 10 minutes
- Replay the packets from the pcap file to the router

```
CLASS,SRC_MAC,SRC_IP,DST_IP,SRC_PORT,DST_PORT,PROTOCOL,PACKETS,FLOWS,BYTES
dns,00:00:00:00:00:03,147.83.42.206,147.83.30.71,64217,53,udp,1,0,72
dns,00:00:00:00:00:03,147.83.30.71,147.83.42.206,53,64217,udp,1,0,214
unclassified,00:00:00:00:00:0e,147.83.42.206,84.88.81.41,3375,7774,tcp,5,0,214
http,00:00:00:00:01:22,98.139.0.22,147.83.42.206,80,3637,tcp,6,0,1296
http,00:00:00:00:01:23,66.196.116.162,147.83.42.206,80,3638,tcp,5,0,653
secure-http,00:00:00:00:01:45,147.83.42.206,173.194.41.240,3413,443,tcp,19,0,1800
secure-http,00:00:00:00:01:45,173.194.41.240,147.83.42.206,443,3413,tcp,20,0,3490
netbios,00:00:00:00:a0:29,147.83.42.206,147.83.2.220,137,137,udp,3,0,288
netbios,00:00:00:00:a0:29,147.83.2.220,147.83.42.206,137,137,udp,3,0,270
ftp,00:00:00:01:eb:58,147.83.42.206,94.75.225.18,3266,21,tcp,11,0,546
ftp,00:00:00:01:eb:58,94.75.225.18,147.83.42.206,21,3266,tcp,15,0,1198
...
```

Figure 4.5: The original log generated by NFACCTD

c) Scrutinizer

Scrutinizer is supposed to be a tool, which can not only collect, but also visualize the network traffic. It consumes a lot of resources, especially RAM (around 700 MB). Furthermore, it does not record the NetFlow v9 packets (but they are captured, because Wireshark can see them arriving).

d) ManageEngine NetFlow Analyzer

In theory, a big flow analyzer, which is supposed to support NetFlow v9 record format, NBAR, etc. It can be downloaded for free from the developer's website [70]. Unfortunately, NBAR #95 field is not detected (and we have no idea why). Furthermore, it cannot even connect to the router by SNMP. The application hangs frequently and it is quite unusable in our approach.

e) Other tools

We did not find any other tools which should support NetFlow v9 format together with the #95 field.

A fragment of the original output from NFACCTD is shown in Figure 4.5.

4.3 Analysis of the Classification Logs

After processing the input data, the DPI tools generate log files, which need to be imported back into the database to analyze the accuracy of the classification. The most challenging part is matching the log records to the proper flows in the database. Thanks to the flow identifier contained by each flow record (either directly or encoded in the source MAC address as it is in the case of NBAR), the job can be done automatically by our *logAnalyzer* tool, which is also a part of the modified VBS system.

4.3.1 Creating a New Database

At first, we create a new database for the analysis purpose. This allows us to store all the data in a compact way, which is not the optimal one from the design point of view, but which speeds up the analysis process. This is thanks to many indexes (almost all columns are indexed) and due to storing the concrete string values instead of just the foreign keys. We start from creating the database for the analysis:

```
java -jar logAnalyzer.jar --createDatabase
```

That creates a new database called *analyzer* with 3 tables inside: *FlowsNormal*, *FlowsCutPackets*, and *FlowsCutFlows*. These tables will be used for storing the results of the classification in all the 3 modes. Before

the import can begin, we need to populate the *flow_id*, *local_ip*, and *labels* fields for every flow in the PCAP file. We did not create any additional tool for this purpose, as we copied these values directly from the *Flows* table in our main database. However, this information can be obtained and imported to the database from the INFO files.
Now, it is time to import the classification logs from all the tested tools.

4.3.2 OpenDPI and L7-filter-aut

The classification logs contains a lot of debug information, which can amount even for 90 % of the file size. Therefore, at first, it is good to decrease the size of the classification log by removing the unnecessary lines by fast Linux GREP tool:

```
grep "#" logFile.old.log > logFile.log
```

That step is not necessary, as *logAnalyzer* can handle the raw output of the classifiers, but it greatly enhances the speed. Afterwards, it is sufficient to run our *logAnalyzer* tool to import the classification results into the database:

```
java -jar logAnalyzer.jar --importOpenDPI_UPCL7Filter_Logs [Normal | CutPackets | CutFlows]
   logFile.log
```

4.3.3 L7-filter-all, L7-filter-sel, and L7-filter-com

The raw outputs of L7-filter classifications do not have any debug information, so no prior filtering of the log is advised. It is sufficient to run our *logAnalyzer* tool to import the classification results into the database. For the first version of the classifier:

```
java -jar logAnalyzer.jar --importL7AllLog [Normal | CutPackets | CutFlows] logFile.log
```

For the second version of the classifier:

```
java -jar logAnalyzer.jar --importL7SelLog [Normal | CutPackets | CutFlows] logFile.log
```

For the third version of the classifier:

```
java -jar logAnalyzer.jar --importL7ComNetLog [Normal | CutPackets | CutFlows] logFile.log
```

4.3.4 NDPI

The raw output of NDPI classification does not have any debug information, so no prior filtering of the log is advised. It is sufficient to run our *logAnalyzer* tool to import the classification results into the database:

```
java -jar logAnalyzer.jar --importNDPILog [Normal | CutPackets | CutFlows] logFile.log
```

4.3.5 Libprotoident

The raw output of Libprotoident classification does not have any debug information, so no prior filtering of the log is advised. It is sufficient to run our *logAnalyzer* tool to import the classification results into the database:

```
java -jar logAnalyzer.jar --importLibprotoidentLog [Normal | CutPackets | CutFlows]
   logFile.log
```

4.3.6 PACE

The raw output of PACE classification does not have any debug information, so no prior filtering of the log is advised. It is sufficient to run our *logAnalyzer* tool to import the classification results into the database:

```
java -jar logAnalyzer.jar --importPACELog [Normal | CutPackets | CutFlows] logFile.log
```

4.3.7 NBAR

The results must be filtered to remove any debug information and the headers. Additionally, we need to filter all flows which were associated directly with the router which was used for the classification by NBAR or with the local network where the router existed. There are many broadcasts and multicasts, Cisco Discovery Protocol flows, etc. So, we need to leave flows which are associated only with the original clients. We can do that using the IP addresses of the clients (they did not change during the experiment).

Importing of the NBAR logs to the database can be done by our *logAnalyzer* tool by:

```
java -jar logAnalyzer.jar --importNBARLog [Normal | CutPackets | CutFlows] logFile.log
```

NBAR relies on NetFlow, which treats the flows in a unidirectional way. It means that we need to assess what is the type of the bi-directional flow based on 2 unidirectional flows (inbound and outbound). The final result of the classification is assessed in the following way:

a) Inbound and outbound flows are of the same class → the class is assigned to the bidirectional flow

b) Either inbound or outbound flow was classified as *unclassified* → the bidirectional flow gets the class from the second unidirectional flow, which was not classified as *unclassified*

c) Both inbound and outbound flows are of different classes, and none of them are *unclassified* → the bidirectional flow gets class from the unidirectional flow, which amounts for more Bytes

4.3.8 Obtaining the Final Results

Our *logAnalyzer* tool can be also used to obtain the final results of classification by all the DPI tools in a condensed form:

```
java -jar logAnalyzer.jar --generateResults
```

The results are stored in the *classification_results.txt* file and they are grouped by:

a) Mode (normal, truncated packets, or truncated flows)

b) Protocol, application, or web service

c) Particular DPI tool

Based on the results, we can calculate all the relevant statistics.

Chapter 5

Results

5.1 Analysis of the Results

The method for analysis of the results depends on the level, on which the flows were labeled. Thanks to this multilevel testing approach, we obtained the knowledge, which classifier is able to provide results on the particular level of classification. That allows to adjust the choice of the DPI technique according to the desired classification level.

5.1.1 Application Protocols

The results given by the classifier must also be on the application protocol level. It means that to consider the classification as correct, the result must be DNS, HTTP, etc, not Flash, or YouTube. Simply, the classifier is tested if it can recognize the specific application protocol. If the result is given as Flash or YouTube, the flow is considered as *unclassified*, as the result is not given on the application protocol level. However, the same flow will be classified as *correct* during other tests, when we for example look for web service YouTube.

5.1.2 Applications

The evaluation of the results on the application level is more complex. We decided to split the applications into 2 groups and assign different evaluation methods to each of these groups:

a) The application uses its proprietary application-level protocol(s)

   For example, Skype can use multiple protocols, including its proprietary protocol called *Skype*, and other protocols, as *HTTP* or *SSL*, which can be used to connect to web servers to download the user's data or advertisements. Therefore, flows labeled by DPI tools as *Skype*, *HTTP*, *SSL*, *STUN*, etc are all marked as *correct*. Specifically:

   - BitTorrent clients: we accept the proprietary *BitTorrent* protocol as well as other protocols used by the application, as HTTP, SSL, STUN, or DNS
   - eDonkey clients: we accept the proprietary *eDonkey* protocol as well as other protocols used by the application, as HTTP, SSL, STUN, or DNS
   - FTP clients: we accept the proprietary *FTP* protocol as well as other protocols used by the application, as HTTP or SSL
   - RDP clients: we accept the proprietary *RDP* protocol as well as other protocols used by the application, as HTTP or SSL

- Skype: we accept the proprietary *Skype* protocol as well as other protocols used by the application, as HTTP, STUN, or SSL. In the general classification, we do not look at the returned sub-types (audio, video, file transfers, etc). The classification of the sub-types is only valid, when the proper sub-type is detected by the classifier

b) The application does not use its proprietary application-level protocol(s), but instead uses HTTP, SSL, etc

It concerns for example Spotify. Then, only the flows marked as *Spotify* are consider to be labeled correctly, as no specific application-level protocol exists, so we expect the application name itself to be identified. Specifically:

- 4Shared: the name of the application or the name of the group (*Direct Download*) must be given
- America's Army: the name of the web service or the name of the integrated *TeamSpeak* must be given. Being detected as *Steam* is not enough, even though this game belongs to the Steam platform
- Dropbox: the name of the application must be given
- Freenet: the name of the application must be given
- iTunes: the name of the application must be given. Being detected as *Apple* is not enough
- League of Legends: the name of the application must be given
- Pando Media Booster: the name of the application must be given
- PPLive: the name of the application must be given
- PPStream: the name of the application must be given
- Sopcast: the name of the application must be given
- Spotify: the name of the application must be given
- Steam: the name of the application must be given
- TOR: the name of the application must be given
- World of Warcraft: the name of the application must be given

5.1.3 Web Services

Generally, the classification is considered to be *correct* only if the name of the web service is given. If the result is given on another level, as HTTP, FLASH, the flow is considered as *unclassified*. More specifically:

- 4Shared: the name of the web service or the name of the group (*Direct Download*) must be given
- Amazon: the name of the web service must be given
- Apple: the name of the web service or the name of any web applications belonging to the service (as *iTunes*) must be given
- Ask: the name of the web service must be given
- Bing: the name of the web service must be given
- Blogspot: the name of the web service or the service group (*Google*) must be given
- CNN: the name of the web service must be given
- Craigslist: the name of the web service must be given

- Cyworld: the name of the web service must be given
- Doubleclick: the name of the web service or the service group (*Google*) must be given
- eBay: the name of the web service must be given
- Facebook: the name of the web service must be given
- Go.com: the name of the web service must be given
- Google: the name of the web service must be given
- Instagram: the name of the web service must be given
- Justin.tv: the name of the web service must be given
- LinkedIn: the name of the web service must be given
- Mediafire: the name of the web service or the name of the group (*Direct Download*) must be given
- MSN: the name of the web service must be given
- MySpace: the name of the web service must be given
- Pinterest: the name of the web service must be given
- Putlocker: the name of the web service or the name of the group (*Direct Download*) must be given
- QQ.com: the name of the web service must be given
- Taobao: the name of the web service must be given
- The Huffington Post: the name of the web service must be given
- Tumblr: the name of the web service must be given
- Twitter: the name of the web service must be given
- Vimeo: the name of the web service must be given
- VK.com: the name of the web service must be given
- Wikipedia: the name of the web service must be given
- Windows Live: the name of the web service (new *Windows Live* or old *Hotmail*) must be given
- Wordpress: the name of the web service must be given
- Yahoo: the name of the web service must be given
- YouTube: the name of the web service or the service group (*Google*) must be given

5.2 Distribution and Level of the Results

In this section, we give an insight into the distribution and level of the results given by each of the classifiers. We grouped all the flows, which participate in the experiment, according to the class assigned by the classifiers and ordered them by the number of flows in each class. The number of the flows in the application classes is obtained from the classifiers and it does not represent the real number of flows, which should be associated with the particular class. The results for the normal dataset (without truncated flows or packets) for the particular classifiers are shown below.

5.2.1 PACE

Regarding the levels of provided results, *PACE* is the best classifier for most of the studied classification groups. This tool is able to provide the results on many various levels at once, as for example *HTTP:generic:facebook*. Other classifiers do not offer this ability at all and only one chosen level is given, so, for example, they do not offer the possibility to account the HTTP or SSL traffic, while they recognize the web service of the transported content. However, PACE is not totally consistent in that matter. Facebook videos (which we observed as transported by HTTP) were detected as, for example, *FLASH:no_subprotocols:facebook*, while the live video streams from Justin.tv using RTMP were classified as *FLASH:no_subprotocols:not_detected*. So, we do not have the knowledge from the results obtained from the classifier which application protocol was used (HTTP, RTMP, or other), because the content container level (*FLASH*) is returned instead. Ideally, the DPI techniques should provide results on all the possible levels, as *TCP:HTTP:Flash:video:Facebook*, so that a kind of consistent accounting could be performed.

Class	No. of Flows	% of Flows
BitTorrent:plain:not_detected	272649	35.52
RDP:no_subprotocols:not_detected	153357	19.98
unknown:no_subprotocols:not_yet_detected	51825	6.75
BitTorrent:uTP:not_detected	46821	6.10
SMB/CIFS:no_subprotocols:not_detected	42808	5.58
NTP:no_subprotocols:not_detected	42227	5.50
SSH:no_subprotocols:not_detected	36615	4.77
HTTP:generic:not_detected	19797	2.58
BitTorrent:encrypted:not_detected	19137	2.49
DNS:no_subprotocols:not_detected	18270	2.38
Pando:no_subprotocols:not_detected	13379	1.74
NETBIOS:no_subprotocols:not_detected	10206	1.33
Yahoo:webmail:not_detected	9468	1.23
eDonkey:plain:not_detected	6884	0.90
HTTP:generic:facebook	5423	0.71
SSL:generic:not_detected	1976	0.26
HTTP:generic:not_yet_detected	1849	0.24
HTTP:generic:youtube	1643	0.21
Socks:socksv5:not_yet_detected	1508	0.20
PPLIVE:no_subprotocols:not_detected	1332	0.17
Skype:unknown:not_detected	1126	0.15
PPSTREAM:no_subprotocols:not_detected	905	0.12
Google:encrypted:not_detected	828	0.11
unknown:no_subprotocols:not_detected	700	0.09
HTTP:media:not_detected	699	0.09
FLASH:no_subprotocols:not_detected	689	0.09
Steam:no_subprotocols:not_detected	665	0.09
HTTP:generic:twitter	555	0.07
FLASH:no_subprotocols:youtube	368	0.05
SSL:generic:facebook	339	0.04
SOPCAST:no_subprotocols:not_detected	281	0.04
SSL:generic:twitter	274	0.04
QQLive:no_subprotocols:not_detected	242	0.03
SPDY:ssl:not_detected	223	0.03
HTTP:generic:ebay	214	0.03
ICMP:no_subprotocols:not_detected	205	0.03
SSL:generic:gmail	159	0.02
TOR:no_subprotocols:not_detected	159	0.02
SSL:generic:amazon_cloud	156	0.02
HTTP:generic:amazon_cloud	153	0.02
DirectDownloadLink:mediafire.com:not_detected	143	0.02
HTTP:generic:itunes	127	0.02
DirectDownloadLink:4shared.com:not_detected	122	0.02

Freenet:no_subprotocols:not_detected	107	0.01
SPDY:ssl:facebook	94	0.01
SSL:generic:dropbox	88	0.01
eDonkey:encrypted:not_detected	75	0.01
SMTP:no_subprotocols:not_detected	67	0.01
Spotify:no_subprotocols:not_detected	63	0.01
HTTP:generic:amazon_shop	57	0.01
MEEBO:unknown:not_detected	52	0.01
Yahoo:unknown:not_detected	43	0.01
SSL:generic:not_yet_detected	40	0.01
IMAP:no_subprotocols:not_detected	35	0.00
Skype:unknown:live_com	33	0.00
QUICKTIME:no_subprotocols:not_detected	31	0.00
SSL:generic:itunes	31	0.00
HTTP:generic:linkedin	30	0.00
QUICKTIME:no_subprotocols:itunes	28	0.00
POP:no_subprotocols:not_detected	26	0.00
Skype:voice:not_detected	25	0.00
WINDOWSMEDIA:no_subprotocols:windowsmedia	23	0.00
Google:plus:not_detected	19	0.00
SSL:generic:linkedin	18	0.00
FTP:control:not_detected	13	0.00
SPDY:ssl:twitter	13	0.00
HTTP:generic:hotmail_webmail	12	0.00
Skype:video:not_detected	12	0.00
MPEG:no_subprotocols:facebook	10	0.00
Skype:out:not_detected	9	0.00
Google:encrypted:not_yet_detected	9	0.00
QUICKTIME:no_subprotocols:youtube	9	0.00
SSL:generic:live_com	8	0.00
HTTP:generic:instagram	8	0.00
MPEG:no_subprotocols:youtube	8	0.00
HTTP:generic:gmail	7	0.00
HTTP:video:youtube	7	0.00
FLASH:no_subprotocols:not_yet_detected	6	0.00
World of Warcraft:no_subprotocols:not_detected	6	0.00
SSL:generic:windows_azure	6	0.00
HTTP:generic:flickr	5	0.00
HTTP:generic:live_com	5	0.00
HTTP:generic:windowsmedia	5	0.00
FLASH:no_subprotocols:facebook	4	0.00
WINDOWSMEDIA:no_subprotocols:not_detected	4	0.00
STUN:no_subprotocols:not_yet_detected	4	0.00
Yahoo:webchat:not_detected	4	0.00
Google:plus:not_yet_detected	4	0.00
Spotify:no_subprotocols:amazon_cloud	4	0.00
MPEG:no_subprotocols:not_detected	3	0.00
WebDAV:no_subprotocols:not_detected	2	0.00
SPDY:ssl:gmail	2	0.00
Google:drive:not_detected	2	0.00
HTTP:generic:myspace	2	0.00
SSL:generic:ebay	2	0.00
Google:docs:googledocs	1	0.00
OGG:no_subprotocols:facebook	1	0.00
unknown:no_subprotocols:facebook	1	0.00
WINDOWSMEDIA:no_subprotocols:youtube	1	0.00

5.2.2 OpenDPI

In most cases, the application protocol name is returned. However, some of the results are given on content container level, as *FLASH*, *QUICKTIME*, or *WINDOWSMEDIA*. In these cases, we do not really know what is the application. For example, *FLASH* content can be transmitted by both *HTTP* or *RTMP* application protocols. Moreover, the *FLASH* content can be streamed (as in *RTMP*) or just downloaded to the user's computer, and then saved to a permanent file, or played by the browser (as in the case of YouTube videos, which use *HTTP*). Furthermore, we do not have knowledge about the service provider names.

Class	No. of Flows	% of Flows
BITTORRENT	211168	27.51
UNKNOWN	192187	25.03
RDP	153369	19.98
SMB	42808	5.58
NTP	42227	5.50
HTTP	41309	5.38
SSH	36615	4.77
DNS	18277	2.38
PANDO	13349	1.74
NETBIOS	10058	1.31
SSL	3457	0.45
FLASH	1073	0.14
EDONKEY	545	0.07
SOPCAST	281	0.04
DIRECT_DOWNLOAD_LINK	264	0.03
FTP	205	0.03
ICMP	205	0.03
QUICKTIME	117	0.02
MAIL_SMTP	67	0.01
MAIL_IMAP	35	0.00
WINDOWSMEDIA	27	0.00
MAIL_POP	26	0.00
PPSTREAM	9	0.00
STUN	4	0.00
STEAM	4	0.00
MPEG	2	0.00
OGG	1	0.00
PPLIVE	1	0.00

5.2.3 L7-filter-all

As we observed, the results were returned always on the application level.

Class	No. of Flows	% of Flows
BITTORRENT_SUBTYPE_PLAIN	286472	37.32
SKYPE_SUBTYPE_SKYPEOUT	152595	19.88
UNKNOWN	126310	16.45
NTP	45412	5.92
SMB	42808	5.58
FINGER	42213	5.50
SSH	36697	4.78
DNS	18207	2.37
EDONKEY_SUBTYPE_PLAIN	5170	0.67
SSL_SUBTYPE_UNKOWN	3303	0.43
SOULSEEK	1928	0.25

SKYPE_SUBTYPE_AUDIO	1655	0.22
HTTP_SUBTYPE_UNKNOWN	1405	0.18
RTP	803	0.10
XUNLEI	790	0.10
KUGOO	457	0.06
QQ	424	0.06
SSL_SUBTYPE_VALIDCERTSSL	393	0.05
SOCKS	197	0.03
ITUNES	152	0.02
TSP	117	0.02
MAIL_SMTP	67	0.01
MAIL_IMAP	35	0.00
MAIL_POP	26	0.00
NBNS	16	0.00
FTP_SUBTYPE_CONTROL	13	0.00
HTTP_SUBTYPE_CACHEHIT	12	0.00
PPLIVE	6	0.00
STUN	3	0.00
ARMAGETRON	3	0.00
H323	1	0.00

5.2.4 L7-filter-sel

As we observed, the results were returned always on the application level.

Class	No. of Flows	% of Flows
UNKNOWN	357974	46.63
BITTORRENT_SUBTYPE_PLAIN	286516	37.32
SMB	42808	5.58
SSH	36697	4.78
DNS	18207	2.37
HTTP_SUBTYPE_UNKNOWN	14389	1.87
SSL_SUBTYPE_UNKOWN	3974	0.52
HTTP_SUBTYPE_CACHEHIT	2390	0.31
SOULSEEK	1928	0.25
XUNLEI	790	0.10
QQ	480	0.06
KUGOO	480	0.06
SSL_SUBTYPE_VALIDCERTSSL	393	0.05
SOCKS	200	0.03
ITUNES	152	0.02
HTTP_SUBTYPE_VIDEO	77	0.01
MAIL_SMTP	67	0.01
HTTP_SUBTYPE_CHACHEMISS	45	0.01
MAIL_IMAP	35	0.00
MAIL_POP	26	0.00
NBNS	24	0.00
FTP_SUBTYPE_CONTROL	13	0.00
PPLIVE	11	0.00
ARMAGETRON	6	0.00
HTTP_SUBTYPE_AUDIO	4	0.00
STUN	3	0.00
H323	1	0.00

5.2.5 L7-filter-aut

As we observed, the results were returned always on the application level when the original rules where used. However, in this modification, we added some rules for discovering web services – in these cases, the web service name is returned.

Class	No. of Flows	% of Flows
UNKNOWN	353737	46.08
BITTORRENT_SUBTYPE_PLAIN	286636	37.34
SMB	42808	5.58
SSH	36697	4.78
DNS	18207	2.37
HTTP_SUBTYPE_UNKNOWN	12271	1.60
FACEBOOK	5438	0.71
SSL_SUBTYPE_UNKOWN	3974	0.52
HTTP_SUBTYPE_CACHEHIT	2383	0.31
SOULSEEK	1928	0.25
YOUTUBE	1560	0.20
TWITTER	554	0.07
QQ	480	0.06
SSL_SUBTYPE_VALIDCERTSSL	393	0.05
SOCKS	200	0.03
ITUNES	152	0.02
MAIL_SMTP	67	0.01
HTTP_SUBTYPE_VIDEO	48	0.01
HTTP_SUBTYPE_CHACHEMISS	45	0.01
MAIL_IMAP	35	0.00
MAIL_POP	26	0.00
NBNS	24	0.00
FTP_SUBTYPE_CONTROL	13	0.00
ARMAGETRON	6	0.00
HTTP_SUBTYPE_AUDIO	4	0.00
STUN	3	0.00
H323	1	0.00

5.2.6 L7-filter-com

As we observed, the results were returned always on the application level.

Class	No. of Flows	% of Flows
BITTORRENT_SUBTYPE_PLAIN	286473	37.32
UNKNOWN	154681	20.15
SKYPE_SUBTYPE_SKYPEOUT	152668	19.89
NTP	45481	5.92
SMB	42808	5.58
SSH	36697	4.78
DNS	18207	2.37
HTTP_SUBTYPE_UNKNOWN	12590	1.64
EDONKEY_SUBTYPE_PLAIN	5186	0.68
SSL_SUBTYPE_UNKOWN	3303	0.43
HTTP_SUBTYPE_CACHEHIT	2354	0.31
SOULSEEK	1928	0.25
SKYPE_SUBTYPE_AUDIO	1665	0.22
RTP	810	0.11
XUNLEI	790	0.10
KUGOO	464	0.06

QQ	427	0.06
SSL_SUBTYPE_VALIDCERTSSL	393	0.05
SOCKS	197	0.03
ITUNES	152	0.02
TSP	118	0.02
HTTP_SUBTYPE_VIDEO	77	0.01
MAIL_SMTP	67	0.01
HTTP_SUBTYPE_CHACHEMISS	44	0.01
MAIL_IMAP	35	0.00
MAIL_POP	26	0.00
NBNS	17	0.00
FTP_SUBTYPE_CONTROL	13	0.00
PPLIVE	7	0.00
ARMAGETRON	4	0.00
ARMAGETRON	4	0.00
STUN	3	0.00
H323	1	0.00

5.2.7 NDPI

NDPI is able to provide the classification on the service provider level, as *facebook*, *google*, or *twitter*. However, the final output of the classification is mixed on different levels. For some flows we only obtain the application name (as *dns* or *bittorrent*), for some we only obtain the content container (as *flash*), and for some we only obtain the service provider name (as *facebook*). Based on the application name, we cannot estimate what is the service provider or the content, and vice versa.

Class	No. of Flows	% of Flows
bittorrent	306679	39.95
rdp	149798	19.51
unknown	57761	7.52
skype	54698	7.13
smb	42808	5.58
ntp	42227	5.50
ssh	36615	4.77
http	36363	4.74
dns	18278	2.38
netbios	10210	1.33
google	9076	1.18
ssl_no_cert	1140	0.15
flash	346	0.05
rtp	305	0.04
edonkey	296	0.04
sopcast	281	0.04
ssl	247	0.03
icmp	205	0.03
ftp	123	0.02
dropbox	80	0.01
H323	40	0.01
imap	35	0.00
pop	26	0.00
TeamSpeak	9	0.00
http_connect	8	0.00
Apple	6	0.00
Tor	6	0.00
facebook	6	0.00
stun	4	0.00
steam	3	0.00

worldofwarcraft	3	0.00
Viber	2	0.00
pops	1	0.00
youtube	1	0.00
ppstream	1	0.00
rtcp	1	0.00
Spotify	1	0.00
yahoo	1	0.00

5.2.8 Libprotoident

The output from the classifier seems to be also structured in an interesting way, since for many application protocols, it gives also information about the transport-layer protocol (as *DNS_TCP*, *BitTorrent_UDP*, or *Unknown_UDP*), which is also unique among all the tested DPI tools. However, many flows obtain the classification only on the content container level (as *Flash_Player*), or the service provider level (as *YahooError*).

Class	No. of Flows	% of Flows
BitTorrent	210829	27.46
RDP	153312	19.97
BitTorrent_UDP	106834	13.92
SMB	42808	5.58
HTTP	42700	5.56
NTP	42227	5.50
Unknown_TCP	39480	5.14
SSH	36697	4.78
Unknown_UDP	34571	4.50
DNS	18267	2.38
Pando	13331	1.74
No_Payload	10904	1.42
HTTPS	4033	0.53
eMule_UDP	3366	0.44
SOCKS5	1927	0.25
Skype	1088	0.14
Steam_UDP	689	0.09
PPLive	675	0.09
EMule	573	0.07
Steam_Friends	505	0.07
RTP	502	0.07
YahooError	410	0.05
RTMP	367	0.05
HTTP_NonStandard	303	0.04
ICMP	205	0.03
FTP_Data	203	0.03
Sopcast	198	0.03
IMAPS	103	0.01
POP3S	101	0.01
Invalid_Bittorrent	84	0.01
SMTP	67	0.01
TOR	62	0.01
SMTP_Secure	52	0.01
IMAP	35	0.00
SSL/TLS	32	0.00
HalfLife	28	0.00
POP3	26	0.00
Pando_UDP	22	0.00
Gnutella_UDP	15	0.00

FTP_Control	13	0.00
PPStream	11	0.00
NetBIOS	11	0.00
STUN	4	0.00
Steam_TCP	4	0.00
NetBIOS_UDP	4	0.00
Web_Junk	3	0.00
WorldOfWarcraft	3	0.00
Spotify	1	0.00
HTTP_443	1	0.00
ApplePush	1	0.00
Kademlia	1	0.00
Mystery_8000	1	0.00
Xunlei	1	0.00

5.2.9 NBAR

This tool provides a very consistent output, as all the results are given on the application level.

Class	No. of Flows	% of Flows
unclassified	442489	57.64
bittorrent	204630	26.66
http	43126	5.62
ssh	36512	4.76
dns	18278	2.38
netbios	10210	1.33
secure-http	4107	0.53
rtp	3434	0.45
h323	2004	0.26
skype	777	0.10
rtcp	418	0.05
edonkey	280	0.04
icmp	205	0.03
ftp	132	0.02
novadigm	123	0.02
citrix	115	0.01
secure-imap	103	0.01
secure-pop3	101	0.01
mgcp	89	0.01
skinny	86	0.01
sap	82	0.01
smtp	67	0.01
nfs	35	0.00
notes	35	0.00
imap	35	0.00
l2tp	33	0.00
socks	29	0.00
sqlnet	29	0.00
pop3	27	0.00
pptp	24	0.00
fasttrack	22	0.00
secure-nntp	12	0.00
sqlserver	12	0.00
cuseeme	9	0.00
xwindows	7	0.00
pcanywhere	7	0.00
irc	2	0.00
rsvp	2	0.00
vdolive	2	0.00

5.3 Evaluation on the Normal Dataset

5.3.1 Application Protocols

The most interesting observations are shown below:

- DNS, HTTP, IMAP-STARTTLS, POP3-PLAIN, SSH are generally well detected by all the classifiers.
- IMAP-TLS is detected only by Libprotoident and NBAR (both with 100 % accuracy), while the rest of the classifiers leave the traffic unclassified (detected as regular SSL flows).
- POP3-TLS and SMTP-TLS are detected only by Libprotoident (with 100 % accuracy), while the rest of the classifiers leave the traffic unclassified (detected as regular SSL flows).
- RTMP is detected only by Libprotoident (85.71–86.51 %). PACE recognizes all these flows as Flash. OpenDPI and NDPI recognize 89 % of these flows as Flash, while the rest is left unclassified. L7-filter misclassified around 23 % of these flows as Skype and TSP.
- SMTP-PLAIN is detected 100 % correctly by all the classifiers except NDPI, which leaves these flows unclassified.
- SOCKSv5 is recognized 100 % correctly only by Libprotoident. PACE also has the ability to recognize SOCKSv5 flows (78.26 %). OpenDPI and NBAR leave the flows as unclassified. NDPI misclassifies all of them as Skype, while L7-filter as Soulseek.
- WEBDAV is detect only by PACE (3.51 %, the rest is left as SSL). The other classifiers leave the flows unclassified (mostly as SSL or HTTPS) – the only exception is NDPI, which misclassifies 96.49 % of the flows as Skype.

The following listing summarizes the classification results:

Protocol	**Classifier**	**Correct** [%]	**Wrong** [%]	**Unclassified** [%]
DNS	PACE	99.95	0.00	0.05
	OpenDPI	99.99	0.00	0.01
	L7-filter-all	99.62	0.05	0.33
	L7-filter-sel	99.62	0.00	0.38
	L7-filter-aut	99.62	0.00	0.38
	L7-filter-com	99.62	0.02	0.36
	NDPI	99.99	0.00	0.01
	Libprotoident	99.96	0.00	0.04
	NBAR	99.99	0.00	0.01
HTTP	PACE	70.92	0.63	28.45
	OpenDPI	95.68	0.59	3.73
	L7-filter-all	3.58	96.04	0.38
	L7-filter-sel	39.51	1.86	58.63
	L7-filter-aut	34.51	0.41	65.08
	L7-filter-com	35.25	10.28	54.47
	NDPI	84.49	0.01	15.50
	Libprotoident	99.80	0.07	0.13
	NBAR	99.04	0.17	0.79

	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
ICMP	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
IMAP	L7-filter-aut	100.00	0.00	0.00
STARTTLS	L7-filter-com	100.00	0.00	0.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
IMAP	L7-filter-aut	0.00	0.00	100.00
TLS	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	0.00	100.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	99.96	0.00	0.04
	OpenDPI	98.51	0.00	1.49
	L7-filter-all	0.00	5.63	94.37
NETBIOS	L7-filter-sel	0.00	0.00	100.00
Name	L7-filter-aut	0.00	0.00	100.00
Service	L7-filter-com	0.00	9.15	90.85
	NDPI	100.00	0.00	0.00
	Libprotoident	0.04	4.94	95.02
	NBAR	100.00	0.00	0.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	9.09	0.00	90.91
NETBIOS	L7-filter-sel	9.09	0.00	90.91
Session	L7-filter-aut	9.09	0.00	90.91
Service	L7-filter-com	9.09	0.00	90.91
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
SAMBA	L7-filter-sel	100.00	0.00	0.00
Session	L7-filter-aut	100.00	0.00	0.00
Service	L7-filter-com	100.00	0.00	0.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	99.86	0.14	0.00
	L7-filter-sel	0.00	0.08	99.92
NTP	L7-filter-aut	0.00	0.08	99.92
	L7-filter-com	99.86	0.13	0.01
	NDPI	100.00	0.00	0.00

	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
POP3	L7-filter-aut	100.00	0.00	0.00
PLAIN	L7-filter-com	100.00	0.00	0.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	5.93	94.06
	L7-filter-sel	0.00	0.00	100.00
POP3	L7-filter-aut	0.00	0.00	100.00
TLS	L7-filter-com	0.00	0.99	99.01
	NDPI	0.01	0.00	99.99
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	23.54	76.46
	L7-filter-sel	0.00	0.53	99.47
RTMP	L7-filter-aut	0.00	0.26	99.74
	L7-filter-com	0.00	23.54	76.46
	NDPI	0.00	4.23	95.77
	Libprotoident	86.51	0.26	13.23
	NBAR	0.00	0.26	99.74
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
SMTP	L7-filter-aut	100.00	0.00	0.00
PLAIN	L7-filter-com	100.00	0.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
SMTP	L7-filter-aut	0.00	0.00	100.00
TLS	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	0.00	100.00
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
	PACE	78.26	0.00	21.74
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	100.00	0.00
SOCKSv5	L7-filter-aut	0.00	100.00	0.00
	L7-filter-com	0.00	100.00	0.00
	NDPI	0.00	100.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
	PACE	93.98	0.51	5.51
	OpenDPI	93.98	0.12	5.90
	L7-filter-all	94.19	0.36	5.45
	L7-filter-sel	94.19	0.12	5.69
SSH	L7-filter-aut	94.19	0.12	5.69

	L7-filter-com	94.19	0.12	5.69
	NDPI	93.98	0.14	5.88
	Libprotoident	94.19	0.36	5.45
	NBAR	93.71	0.64	5.65
Webdav	PACE	3.51	0.00	96.49
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	7.02	92.98
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	7.02	92.98
	NDPI	0.00	96.49	3.51
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00

5.3.2 Applications

The most interesting observations are shown below:

- 4Shared downloading client is usually misclassified by NDPI as Skype (72.92 %).
- America's Army game is not classified by any tool. L7-filter misclassifies 97.71 % of this traffic as Skype, NBAR 72.00 % as RTP, while Libprotoident 89.14 % as Steam. Steam is in fact the provider of the America's Army game, but the game is not the same as Steam itself.
- Non-encrypted traffic from BitTorrent clients is generally well detected by all the classifiers. Encrypted BitTorrent protocol is often misclassified by NDPI as Skype (23.68 %).
- Dropbox, when it is not identified, is recognized usually as SSL or HTTPS. NDPI, however, gave us 12.90 % of misclassifications as Skype.
- Obfuscated eDonkey protocol is difficult to identify. NDPI gave us 60.55 % of misclassifications as Skype and L7-filter-all 16.59 % as Finger, RTP, and Skype. Plain eDonkey protocol is an interesting case, as the accuracy provided by PACE (16.50 %) was lower than in the case of the obfuscated protocol (36.06 %). NDPI gave us 54.69 % misclassifications as Skype and L7-filter-all 16.32 % as Finger, RTP, and Skype.
- Freenet is supposed to be very hard to detect. It is only recognized by PACE. L7-filter-all gave us 20.00 % of misclassifications as Finger, Skype, and NTP. L7-filter-com misclassified 14.07 % of flows as Skype and NTP. NDPI misclassified 15.56 % of flows as Skype, and NBAR 15.56 % as RTP.
- FTP in the active mode is a very interesting case, as only Libprotoident is able to recognize 100 % of the flows. PACE and L7-filter are not able to recognize more than 5.56 % of flows. L7-filter misclassified over 90 % of flows as Skype or SOCKS.
- FTP in the passive mode is identified even less accurately than in the active mode. Libprotoident detects 22.95 % of flows a BitTorrent. NDPI cannot identify this protocol at all, labeling 98.36 % of flows as Skype. L7-filter misclassifies around 75 % of flows as SOCKS.
- iTunes is labeled by NDPI as Skype in 16.17 % of cases. Non-recognized cases are labeled mostly as HTTP, SSL or HTTPS.
- League of Legends is not detected by any of these classifiers. L7-filter-all gives 69.57 % of misclassifications as Finger.
- PPLive is misclassified by NDPI as Skype (44.97 %) and by L7-filter-all as Finger, Xunlei, Skype, and NTP (56.03 %).

- PPStream is misclassified by NDPI Skype (80.54 %) and by L7-filter-all as Finger, Skype, NTP, and TSP (38.39 %).
- RDP is misclassified by L7-filter as Skype (over 92 %).
- Skype is misclassified by L7-filter as RTP, Finger, eDonkey, or NTP (24.67–31.70 %). Voice conversations are misclassified in 14.29 % as Finger by L7-filter-all. OpenDPI does not recognize these flows at all, while NDPI and NBAR recognize the flows as Skype without providing the subtype. Video sessions and file transfers are not recognized by any classifier. NDPI and NBAR recognize them as Skype without providing the subtype, while PACE and L7-filter detect them as Skype voice flows.
- Sopcast flows are almost totally misclassified by L7-filter-all as Skype, Finger, or Xunlei (99.06 %). In case of L7-filter-com, the misclassification rate is 74.76 %.
- Spotify is misclassified by NDPI as Skype (47.75 %) and by L7-filter-all as Finger and Skype (around 43 %).
- Steam is misclassified by NDPI as Skype (43.82 %) and by L7-filter-all as Finger and Skype (65.89 %). The unclassified flows are usually marked as HTTP.
- TOR traffic is intentionally supposed to be difficult to discover. Despite that, it is recognized accurately by PACE (85.95 %). Libprotoident maintains the accuracy of 33.51 %, while NDPI, achieves 3.24 % of accuracy. NDPI misclassifies 86.40 % of flows as Skype. The unclassified flows are usually marked as SSL or HTTPS.
- World of Warcraft is usually misclassified by L7-filter-all as Finger and Skype (86.36 %). The unclassified flows are usually marked as HTTP.

The following listing summarizes the classification results:

Application	**Classifier**	**Correct** [%]	**Wrong** [%]	**Unclassified** [%]
4Shared	PACE	27.08	0.00	72.92
	OpenDPI	27.08	0.00	72.92
	L7-filter-all	0.00	1.39	98.61
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	72.92	27.08
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
America's Army	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	97.71	2.29
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	97.43	2.57
	NDPI	2.57	40.57	56.86
	Libprotoident	0.00	89.14	10.86
	NBAR	0.00	72.00	28.00
BitTorrent clients (encrypted)	PACE	78.68	0.05	21.27
	OpenDPI	0.27	0.00	99.73
	L7-filter-all	40.54	10.17	49.29
	L7-filter-sel	40.65	0.70	58.65
	L7-filter-aut	40.65	0.26	59.09
	L7-filter-com	40.62	7.30	52.08
	NDPI	53.82	23.68	22.50
	Libprotoident	60.31	0.02	39.67
	NBAR	1.29	0.63	98.08

	PACE	99.87	0.00	0.13
	OpenDPI	80.61	0.00	19.39
	L7-filter-all	94.56	0.49	4.95
BitTorrent	L7-filter-sel	94.60	0.08	5.32
clients	L7-filter-aut	94.61	0.07	5.32
(non-encrypted)	L7-filter-com	94.60	0.42	4.98
	NDPI	97.48	2.36	0.16
	Libprotoident	99.30	0.00	0.70
	NBAR	77.84	0.36	21.80
	PACE	94.62	0.00	5.38
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
Dropbox	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	86.02	12.90	1.08
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	36.06	7.26	56.68
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	11.64	16.59	71.77
eDonkey	L7-filter-sel	0.00	0.10	99.90
clients	L7-filter-aut	0.00	0.02	99.98
(obfuscated)	L7-filter-com	11.64	11.09	77.27
	NDPI	0.00	60.55	39.45
	Libprotoident	11.47	0.00	88.53
	NBAR	0.00	15.93	84.07
	PACE	16.50	3.74	79.76
	OpenDPI	3.98	0.30	95.72
	L7-filter-all	17.97	16.32	65.71
eDonkey	L7-filter-sel	0.04	0.39	99.57
clients	L7-filter-aut	0.04	0.31	99.65
(non-obfuscated)	L7-filter-com	17.99	10.79	71.22
	NDPI	2.17	54.69	43.14
	Libprotoident	17.86	0.31	81.83
	NBAR	2.05	11.19	86.76
	PACE	79.26	0.00	20.74
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	20.00	80.00
	L7-filter-sel	0.00	2.22	97.78
Freenet	L7-filter-aut	0.00	0.74	99.26
	L7-filter-com	0.00	14.07	85.93
	NDPI	0.00	15.56	84.44
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	15.56	84.44
	PACE	5.56	0.00	94.44
	OpenDPI	97.62	0.00	2.38
	L7-filter-all	5.56	92.06	2.38
FTP	L7-filter-sel	5.56	90.47	3.97
clients	L7-filter-aut	5.56	90.47	3.97
(active)	L7-filter-com	5.56	90.47	3.97
	NDPI	97.62	0.00	2.38
	Libprotoident	100.00	0.00	0.00
	NBAR	50.79	0.00	49.21
	PACE	4.92	0.00	95.08
	OpenDPI	67.21	0.00	32.79
	L7-filter-all	4.92	76.23	23.77
FTP	L7-filter-sel	4.92	72.13	27.87
clients	L7-filter-aut	4.92	71.31	28.69
(passive)	L7-filter-com	4.92	73.77	26.23
	NDPI	0.00	98.36	1.64

	Libprotoident	73.77	22.95	3.28
	NBAR	50.00	0.00	50.00
iTunes	PACE	77.45	0.00	22.55
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	63.83	6.81	29.36
	L7-filter-sel	63.83	0.00	36.17
	L7-filter-aut	63.83	0.00	36.17
	L7-filter-com	63.83	0.00	36.17
	NDPI	0.00	16.17	83.83
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
League of Legends	PACE	0.00	13.04	86.96
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	69.57	30.43
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	13.04	86.96
	L7-filter-com	0.00	4.35	95.65
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	4.35	95.65
	NBAR	0.00	0.00	100.00
Pando Media Booster	PACE	99.45	0.39	0.16
	OpenDPI	99.23	0.54	0.23
	L7-filter-all	0.00	0.74	99.26
	L7-filter-sel	0.00	0.39	99.61
	L7-filter-aut	0.00	0.39	99.61
	L7-filter-com	0.00	0.55	99.45
	NDPI	0.00	0.41	99.59
	Libprotoident	99.26	0.41	0.33
	NBAR	0.00	0.36	99.64
PPLive	PACE	88.21	0.00	11.79
	OpenDPI	0.07	0.13	99.80
	L7-filter-all	0.00	56.03	43.97
	L7-filter-sel	0.00	7.95	92.05
	L7-filter-aut	0.00	0.07	99.93
	L7-filter-com	0.00	17.15	82.85
	NDPI	0.00	44.97	55.03
	Libprotoident	44.70	0.13	55.17
	NBAR	0.00	0.40	99.60
PPStream	PACE	79.32	0.00	20.68
	OpenDPI	0.79	0.00	99.21
	L7-filter-all	0.00	38.39	61.61
	L7-filter-sel	0.00	1.67	98.33
	L7-filter-aut	0.00	0.09	99.91
	L7-filter-com	0.00	15.07	84.93
	NDPI	0.09	80.54	19.37
	Libprotoident	0.96	0.00	99.04
	NBAR	0.00	5.26	94.74
RDP clients	PACE	99.69	0.00	0.31
	OpenDPI	99.70	0.00	0.30
	L7-filter-all	0.00	92.25	7.75
	L7-filter-sel	0.00	0.01	99.99
	L7-filter-aut	0.00	0.01	99.99
	L7-filter-com	0.00	92.25	7.75
	NDPI	97.37	2.34	0.29
	Libprotoident	99.66	0.01	0.33
	NBAR	0.00	0.67	99.33
Skype	PACE	83.51	5.05	11.44
	OpenDPI	38.49	0.32	61.19
	L7-filter-all	59.21	31.70	9.09
	L7-filter-sel	35.51	0.92	63.57
	L7-filter-aut	35.37	0.96	63.67

(all)	L7-filter-com	62.52	24.67	12.81
	NDPI	99.36	0.64	0.00
	Libprotoident	88.75	0.00	11.25
	NBAR	70.37	3.40	26.23
Skype (audio)	PACE	100.00	0.00	0.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	85.71	14.29	0.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	100.00	0.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Skype (file transfer)	PACE	0.00	100.00	0.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	16.67	83.33
	L7-filter-aut	0.00	16.67	83.33
	L7-filter-com	0.00	100.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Skype (video)	PACE	0.00	100.00	0.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	14.29	85.71
	L7-filter-aut	0.00	14.29	85.71
	L7-filter-com	0.00	100.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Sopcast	PACE	66.27	3.07	30.66
	OpenDPI	66.27	2.59	31.14
	L7-filter-all	0.00	99.06	0.94
	L7-filter-sel	0.00	4.72	95.28
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	74.76	25.24
	NDPI	66.27	5.19	28.54
	Libprotoident	46.70	0.24	53.06
	NBAR	0.00	0.00	100.00
Spotify	PACE	37.64	2.25	60.11
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	43.26	56.74
	L7-filter-sel	0.00	1.12	98.88
	L7-filter-aut	0.00	1.69	98.31
	L7-filter-com	0.00	10.11	89.89
	NDPI	0.56	47.75	51.69
	Libprotoident	0.56	0.00	99.44
	NBAR	0.00	0.56	99.44
Steam	PACE	55.19	0.75	44.06
	OpenDPI	0.33	0.00	99.67
	L7-filter-all	0.00	65.89	34.11
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.73	95.27
	NDPI	0.25	43.82	55.93
	Libprotoident	75.85	0.00	24.15
	NBAR	0.00	0.58	99.42
	PACE	85.95	0.00	14.05
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00

TOR	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	3.24	86.49	10.27
	Libprotoident	33.51	0.00	66.49
	NBAR	0.00	2.16	97.84
World of Warcraft	PACE	27.27	0.00	72.73
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	86.36	13.64
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	22.73	77.27
	NDPI	13.64	4.55	81.81
	Libprotoident	13.64	0.00	86.36
	NBAR	0.00	0.00	100.00

5.3.3 Web Services

The most interesting observations are shown below:

- PACE recognizes 4Shared (84.69 %), Amazon (58.97 %), Apple (0.84 %), Blogspot (3.83 %), eBay (67.97 %), Facebook (80.79 %), Google (10.79 %), Instagram (88.89 %), Linkedin (77.42 %), Mediafire (30.30 %), Myspace (100 %), QQ.com (32.14 %), Twitter (71.18 %), Windows Live (96.15 %), Yahoo (54.70 %), and YouTube (81.97 %). PACE does not have problems with recognizing SSL flows belonging to these services, which means that PACE must use other techniques than just looking directly into the packets to associate the flows with the particular services.
- OpenDPI recognizes only Direct Download websites: 4Shared (83.67 %) and MediaFire (30.30 %).
- L7-filter recognizes only Apple (0.42 %). L7-filter (especially L7-filter-all) is characterized by a very high number of misclassified flows belonging to web services (usually 80–99 %). The flows are recognized in a vast majority as Finger and Skype.
- NDPI recognizes Apple (1.26 %), Blogspot (93.19 %), Doubleclick (95.12 %), Facebook (0.09 %), Google (74.10 %), Yahoo (0.01 %), and YouTube (75.73 %). In some cases (LinkedIn: 33.87 %, Mediafire: 69.07 %, Vimeo: 27.00 %), the flows are misclassified as Skype.
- Libprotoident recognizes only Yahoo (2.36 %).
- NBAR does not recognize any web services.

The following listing summarizes the classification results:

Web Service	**Classifier**	**Correct** [%]	**Wrong** [%]	**Unclassified** [%]
4Shared	PACE	84.69	0.00	15.31
	OpenDPI	83.67	0.00	16.33
	L7-filter-all	0.00	84.69	15.31
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	65.31	34.69
	NDPI	0.00	4.08	95.92
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00

	PACE	58.97	0.00	41.03
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	70.10	29.90
	L7-filter-sel	0.00	1.33	98.67
Amazon	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	40.53	59.47
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.83	99.17
	NBAR	0.00	0.00	100.00
	PACE	0.84	3.98	95.18
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.42	75.47	24.11
	L7-filter-sel	0.42	0.00	99.58
Apple	L7-filter-aut	0.42	0.00	99.58
	L7-filter-com	0.42	5.87	93.71
	NDPI	1.26	0.21	98.53
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	98.83	1.17
	L7-filter-sel	0.00	0.00	100.00
Ask	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	56.14	43.86
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	94.08	5.92
	L7-filter-sel	0.00	0.00	100.00
Bing	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.88	99.12
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	3.83	0.00	96.17
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	87.66	12.34
	L7-filter-sel	0.00	0.43	99.57
Blogspot	L7-filter-aut	0.00	0.43	99.57
	L7-filter-com	0.00	2.98	97.02
	NDPI	93.19	1.70	5.11
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	89.88	10.12
	L7-filter-sel	0.00	0.40	99.60
CNN	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	2.43	97.57
	NDPI	0.00	10.53	89.47
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	91.62	8.38
	L7-filter-sel	0.00	0.00	100.00
Craigslist	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	1.68	98.32
	NDPI	0.00	0.00	100.00

	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Cyworld	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	79.82	20.18
	L7-filter-sel	0.00	1.20	98.80
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	28.31	71.69
	NDPI	0.00	6.93	93.07
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Doubleclick	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.46	15.54
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	9.80	90.20
	NDPI	95.12	0.30	4.58
	Libprotoident	0.00	0.05	99.95
	NBAR	0.00	0.00	100.00
eBay	PACE	67.97	0.00	32.03
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	70.11	29.89
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	1.42	98.58
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Facebook	PACE	80.79	0.00	19.21
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	76.99	23.01
	L7-filter-sel	0.00	0.01	99.99
	L7-filter-aut	78.17	0.00	21.83
	L7-filter-com	0.00	6.57	93.43
	NDPI	0.09	0.42	99.49
	Libprotoident	0.00	0.01	99.99
	NBAR	0.00	0.00	100.00
Go.com	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	76.72	23.28
	L7-filter-sel	0.00	0.30	99.70
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	11.34	86.66
	NDPI	0.00	2.39	97.61
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Google	PACE	10.79	0.00	89.21
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	60.36	39.64
	L7-filter-sel	0.00	0.11	99.89
	L7-filter-aut	0.00	0.09	99.91
	L7-filter-com	0.00	17.66	82.34
	NDPI	74.10	2.52	23.38
	Libprotoident	0.00	0.08	99.92
	NBAR	0.00	0.00	100.00
Instagram	PACE	88.89	0.00	11.11
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	88.89	11.11
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00

	L7-filter-com	0.00	11.11	88.89
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Justin.tv	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	87.23	12.77
	L7-filter-sel	0.00	20.38	79.62
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	25.15	74.85
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.30	99.70
	NBAR	0.00	0.00	0.00
LinkedIn	PACE	77.42	0.00	22.58
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	48.39	51.61
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	3.23	96.77
	NDPI	0.00	33.87	66.13
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Mediafire	PACE	30.30	0.00	69.70
	OpenDPI	30.30	0.00	69.70
	L7-filter-all	0.00	30.08	69.92
	L7-filter-sel	0.00	0.21	99.79
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.45	95.55
	NDPI	0.00	69.07	30.93
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
MSN	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	75.54	24.46
	L7-filter-sel	0.00	0.32	99.68
	L7-filter-aut	0.00	0.32	99.68
	L7-filter-com	0.00	11.75	88.25
	NDPI	0.00	4.53	95.47
	Libprotoident	0.00	0.22	99.78
	NBAR	0.00	0.00	100.00
Myspace	PACE	100.00	0.00	0.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Pinterest	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	82.54	17.46
	L7-filter-sel	0.00	2.65	97.35
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	21.16	78.84
	NDPI	0.00	3.70	96.30
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	73.79	26.21

	L7-filter-sel	0.00	1.94	98.06
Putlocker	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	33.98	67.02
	NDPI	0.00	1.94	98.06
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	32.14	0.00	67.86
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	63.61	36.39
	L7-filter-sel	0.00	0.13	99.87
QQ.com	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	9.43	90.57
	NDPI	0.00	2.79	97.21
	Libprotoident	0.00	0.13	99.87
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	81.14	18.86
	L7-filter-sel	0.00	0.00	100.00
Taobao	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	5.17	94.83
	NDPI	0.00	0.52	99.48
	Libprotoident	0.00	0.26	99.74
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	94.37	5.63
The	L7-filter-sel	0.00	2.82	97.18
Huffington	L7-filter-aut	0.00	0.00	100.00
Post	L7-filter-com	0.00	28.17	71.83
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	73.45	26.55
	L7-filter-sel	0.00	1.24	98.76
Tumblr	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	6.20	93.80
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	71.18	0.00	28.82
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	52.46	47.54
	L7-filter-sel	0.00	11.25	88.75
Twitter	L7-filter-aut	48.68	0.00	51.32
	L7-filter-com	0.00	30.32	69.68
	NDPI	0.00	1.32	98.68
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	50.38	49.62
	L7-filter-sel	0.00	0.00	100.00
Vimeo	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	3.82	96.18
	NDPI	0.00	26.72	73.28
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	0.00

	OpenDPI	0.00	0.00	0.00
	L7-filter-all	0.00	97.38	2.62
	L7-filter-sel	0.00	0.00	100.00
Vk.com	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	3.50	96.50
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	68.70	31.30
	L7-filter-sel	0.00	0.02	99.98
Wikipedia	L7-filter-aut	0.00	0.02	99.98
	L7-filter-com	0.00	0.57	99.43
	NDPI	0.00	0.07	99.93
	Libprotoident	0.00	0.03	99.97
	NBAR	0.00	0.00	100.00
	PACE	96.15	0.00	3.85
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	65.38	34.62
Windows	L7-filter-sel	0.00	0.00	100.00
Live	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.62	15.38
	L7-filter-sel	0.00	0.00	100.00
Wordpress	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	8.28	91.72
	NDPI	0.00	0.59	99.41
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	54.70	0.17	45.13
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.81	15.19
	L7-filter-sel	0.00	0.05	99.95
Yahoo	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.43	95.57
	NDPI	0.01	0.00	99.99
	Libprotoident	2.36	0.00	97.64
	NBAR	0.00	0.01	99.99
	PACE	81.97	0.00	18.03
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	81.85	18.15
	L7-filter-sel	0.00	0.32	99.68
YouTube	L7-filter-aut	61.21	0.00	38.79
	L7-filter-com	0.00	7.66	92.34
	NDPI	75.73	0.24	24.03
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00

5.4 Evaluation on the Dataset with Truncated Packets

5.4.1 Application Protocols

The most interesting observations are shown below:

- Truncation of packets has a considerable impact on the classification of most application protocols by all tools except Libprotoident and NBAR, which tend to maintain their normal accuracy.

The following listing summarizes the classification results:

Protocol	**Classifier**	**Correct [%]**	**Wrong [%]**	**Unclassified [%]**
DNS	PACE	99.95	0.00	0.05
	OpenDPI	99.99	0.00	0.01
	L7-filter-all	1.54	12.40	86.06
	L7-filter-sel	1.56	0.79	97.65
	L7-filter-aut	1.56	0.06	98.38
	L7-filter-com	1.55	7.76	90.69
	NDPI	99.99	0.00	0.01
	Libprotoident	99.96	0.00	0.04
	NBAR	99.99	0.00	0.01
HTTP	PACE	0.76	0.00	99.24
	OpenDPI	0.76	0.00	99.24
	L7-filter-all	0.00	99.98	0.02
	L7-filter-sel	0.00	4.04	95.96
	L7-filter-aut	0.00	0.13	99.87
	L7-filter-com	0.00	17.09	82.91
	NDPI	1.39	0.01	98.60
	Libprotoident	99.80	0.07	0.13
	NBAR	97.27	0.17	2.56
ICMP	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
IMAP STARTTLS	PACE	0.00	100.00	0.00
	OpenDPI	0.00	100.00	0.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
	L7-filter-aut	100.00	0.00	0.00
	L7-filter-com	100.00	0.00	0.00
	NDPI	0.00	100.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
IMAP TLS	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	0.00	100.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
NETBIOS Name Service	PACE	66.48	0.00	33.52
	OpenDPI	98.51	0.00	1.49
	L7-filter-all	0.00	5.63	94.37
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	9.15	90.85
	NDPI	98.51	0.00	1.49
	Libprotoident	0.04	4.94	95.02
	NBAR	100.00	0.00	0.00

	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	0.00	0.00	100.00
NETBIOS	L7-filter-sel	0.00	0.00	100.00
Session	L7-filter-aut	0.00	0.00	100.00
Service	L7-filter-com	0.00	0.00	100.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	99.95	0.00	0.05
	OpenDPI	99.95	0.00	0.05
	L7-filter-all	99.95	0.00	0.05
SAMBA	L7-filter-sel	99.95	0.00	0.05
Session	L7-filter-aut	99.95	0.00	0.05
Service	L7-filter-com	99.95	0.00	0.05
	NDPI	99.95	0.00	0.05
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	99.86	0.14	0.00
	L7-filter-sel	0.00	0.08	99.92
NTP	L7-filter-aut	0.00	0.08	99.92
	L7-filter-com	99.86	0.13	0.01
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
POP3	L7-filter-aut	100.00	0.00	0.00
PLAIN	L7-filter-com	100.00	0.00	0.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	5.93	94.06
	L7-filter-sel	0.00	0.00	100.00
POP3	L7-filter-aut	0.00	0.00	100.00
TLS	L7-filter-com	0.00	0.99	99.01
	NDPI	86.14	0.00	13.86
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	22.49	77.51
	L7-filter-sel	0.00	0.79	99.21
RTMP	L7-filter-aut	0.00	0.79	99.21
	L7-filter-com	0.00	22.49	77.51
	NDPI	0.00	28.84	71.16
	Libprotoident	86.51	0.26	13.23
	NBAR	0.00	0.26	99.74
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
SMTP	L7-filter-aut	100.00	0.00	0.00
PLAIN	L7-filter-com	100.00	0.00	0.00
	NDPI	0.00	0.00	100.00

	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
SMTP TLS	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	3.85	0.00	96.15
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
SOCKSv5	PACE	78.26	0.00	21.74
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	100.00	0.00
	L7-filter-aut	0.00	100.00	0.00
	L7-filter-com	0.00	100.00	0.00
	NDPI	0.00	100.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
SSH	PACE	93.98	0.00	6.02
	OpenDPI	93.98	0.00	6.02
	L7-filter-all	7.90	86.65	5.45
	L7-filter-sel	7.90	0.00	92.10
	L7-filter-aut	7.90	0.00	92.10
	L7-filter-com	7.90	86.42	5.68
	NDPI	93.98	0.02	6.00
	Libprotoident	94.19	0.36	5.45
	NBAR	93.71	0.52	5.77
Webdav	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	3.51	96.49
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	3.51	96.49
	NDPI	0.00	100.00	0.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00

5.4.2 Applications

The most interesting observations are shown below:

- Truncation of packets has a considerable impact on the classification of most applications by all tools except Libprotoident, which tends to maintain its normal accuracy.
- L7-filter is not able to detect DNS traffic on this set, while all the other classifiers present the accuracy of over 99 %.
- IMAP-STARTTLS is detected 100 % correctly by all the classifiers on all the sets, except PACE, OpenDPI, and NDPI, which cannot detect this protocol on the set with truncated packets and leaves these flows unclassified (they are detected as regular SSL flows).
- NBAR cannot detect NTP on the normal set, while it detects it 100 % correctly on the set with truncated packets.
- NDPI has the ability to recognize POP3-TLS (86.14 %) and SMTP-TLS (3.85 %) only on the set with truncated packets, while on the normal dataset the traffic is recognized as SSL.

- The detection rate of SSH by L7-filter drops to 7.90 % on this set, while all other classifier maintain their normal accuracy.
- The detection rate of Skype by NDPI increases from 72.99 % (on the normal dataset) to 91.92 % (truncated packets).

The following listing summarizes the classification results:

Application	**Classifier**	**Correct [%]**	**Wrong [%]**	**Unclassified [%]**
4Shared	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	27.08	72.92
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	97.22	2.78
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
America's Army	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	94.57	5.43
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	94.29	5.71
	NDPI	2.57	40.57	56.86
	Libprotoident	0.00	89.14	10.86
	NBAR	0.00	72.00	28.00
BitTorrent clients (encrypted)	PACE	59.59	0.09	40.32
	OpenDPI	0.01	0.00	99.99
	L7-filter-all	40.49	9.97	49.54
	L7-filter-sel	40.52	0.85	58.63
	L7-filter-aut	40.52	0.41	59.07
	L7-filter-com	40.49	7.07	52.44
	NDPI	53.83	23.80	23.37
	Libprotoident	60.31	0.02	39.67
	NBAR	0.14	3.41	96.45
BitTorrent clients (non-encrypted)	PACE	18.54	15.57	65.89
	OpenDPI	0.01	0.00	99.99
	L7-filter-all	14.01	81.02	4.97
	L7-filter-sel	14.02	0.06	85.92
	L7-filter-aut	14.02	0.06	85.92
	L7-filter-com	14.01	80.95	5.04
	NDPI	16.53	14.89	68.58
	Libprotoident	99.30	0.00	0.70
	NBAR	0.06	0.98	98.96
Dropbox	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	86.02	12.90	1.08
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
eDonkey clients (obfuscated)	PACE	34.37	0.00	65.63
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	11.66	16.49	71.85
	L7-filter-sel	0.04	0.09	99.87
	L7-filter-aut	0.04	0.01	99.95
	L7-filter-com	11.66	11.00	77.34

	NDPI	0.00	60.55	39.45
	Libprotoident	11.47	0.00	88.53
	NBAR	0.00	13.22	86.78
	PACE	10.70	0.00	89.30
	OpenDPI	1.95	0.00	98.05
	L7-filter-all	17.97	16.28	65.75
eDonkey	L7-filter-sel	0.06	0.09	99.85
clients	L7-filter-aut	0.07	0.02	99.91
(non-obfuscated)	L7-filter-com	17.97	10.74	71.29
	NDPI	0.36	54.48	45.16
	Libprotoident	17.86	0.31	81.83
	NBAR	2.16	11.20	86.64
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	19.26	80.74
	L7-filter-sel	0.00	1.48	98.52
Freenet	L7-filter-aut	0.00	0.74	99.26
	L7-filter-com	0.00	13.33	86.67
	NDPI	0.00	15.56	84.44
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	15.56	84.44
	PACE	1.59	0.00	98.41
	OpenDPI	47.62	0.00	52.38
	L7-filter-all	0.00	96.83	3.17
FTP	L7-filter-sel	0.00	0.00	100.00
clients	L7-filter-aut	0.00	0.00	100.00
(active)	L7-filter-com	0.00	95.24	4.76
	NDPI	47.62	0.00	52.38
	Libprotoident	100.00	0.00	0.00
	NBAR	5.56	0.00	94.44
	PACE	1.64	0.00	98.36
	OpenDPI	1.64	0.00	98.36
	L7-filter-all	0.00	75.41	24.59
FTP	L7-filter-sel	0.00	0.00	100.00
clients	L7-filter-aut	0.00	0.00	100.00
(passive)	L7-filter-com	0.00	72.95	27.05
	NDPI	0.00	98.36	1.64
	Libprotoident	73.77	22.95	3.28
	NBAR	4.92	0.00	95.08
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	70.64	29.36
	L7-filter-sel	0.00	0.00	100.00
iTunes	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	70.64	29.36
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	69.57	30.43
League	L7-filter-sel	0.00	0.00	100.00
of	L7-filter-aut	0.00	0.00	100.00
Legends	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	56.52	43.38
	Libprotoident	0.00	4.35	95.65
	NBAR	0.00	0.00	100.00
	PACE	97.70	0.00	2.30
	OpenDPI	97.70	0.00	2.30
	L7-filter-all	0.00	0.80	99.20
Pando	L7-filter-sel	0.00	0.00	100.00

Media Booster	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.62	99.38
	NDPI	0.00	53.85	46.15
	Libprotoident	99.26	0.41	0.33
	NBAR	0.00	0.13	99.87
PPLive	PACE	45.50	0.00	54.50
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	56.03	43.97
	L7-filter-sel	0.00	1.46	98.54
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	10.66	89.34
	NDPI	0.00	90.53	9.47
	Libprotoident	44.70	0.00	55.30
	NBAR	0.00	8.01	91.99
PPStream	PACE	63.37	0.00	36.63
	OpenDPI	0.79	0.00	99.21
	L7-filter-all	0.00	38.30	61.70
	L7-filter-sel	0.00	1.58	98.42
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	14.99	85.01
	NDPI	0.09	89.40	10.51
	Libprotoident	0.96	0.00	99.04
	NBAR	0.00	7.10	92.90
RDP clients	PACE	98.47	0.00	1.53
	OpenDPI	98.48	0.00	1.52
	L7-filter-all	0.00	99.64	0.36
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	99.64	0.36
	NDPI	96.16	3.55	0.29
	Libprotoident	99.66	0.01	0.33
	NBAR	0.00	0.49	99.51
Skype (all)	PACE	82.32	0.00	17.68
	OpenDPI	26.23	0.00	73.77
	L7-filter-all	66.10	11.44	22.46
	L7-filter-sel	17.80	0.87	81.33
	L7-filter-aut	17.80	0.64	81.56
	L7-filter-com	66.10	4.36	29.54
	NDPI	95.77	0.64	3.59
	Libprotoident	88.75	0.00	11.25
	NBAR	70.37	3.40	26.23
Skype (audio)	PACE	100.00	0.00	0.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	85.71	14.29	0.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	100.00	0.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Skype (file transfer)	PACE	0.00	100.00	0.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	16.67	83.33
	L7-filter-aut	0.00	16.67	83.33
	L7-filter-com	0.00	100.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	100.00	0.00
	OpenDPI	0.00	0.00	100.00

	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	28.57	71.43
Skype	L7-filter-aut	0.00	28.57	71.43
(video)	L7-filter-com	0.00	100.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	66.27	0.00	33.73
	OpenDPI	66.27	0.00	33.73
	L7-filter-all	0.00	99.06	0.94
	L7-filter-sel	0.00	4.95	95.05
Sopcast	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	74.76	25.24
	NDPI	66.27	32.31	1.42
	Libprotoident	46.70	0.24	53.06
	NBAR	0.00	46.46	53.54
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	46.07	53.93
	L7-filter-sel	0.00	1.12	98.88
Spotify	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	12.92	87.08
	NDPI	0.56	81.46	17.98
	Libprotoident	0.56	0.00	99.44
	NBAR	0.00	0.56	99.44
	PACE	32.03	0.00	67.97
	OpenDPI	0.33	0.00	99.67
	L7-filter-all	0.00	66.06	33.94
	L7-filter-sel	0.00	0.00	100.00
Steam	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.65	95.35
	NDPI	0.25	51.70	48.05
	Libprotoident	75.85	0.00	24.15
	NBAR	0.00	0.58	99.42
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
TOR	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	3.24	86.49	10.27
	Libprotoident	33.51	0.00	66.49
	NBAR	0.00	0.54	99.46
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	86.36	13.64
World	L7-filter-sel	0.00	0.00	100.00
of	L7-filter-aut	0.00	0.00	100.00
Warcraft	L7-filter-com	0.00	22.73	77.27
	NDPI	0.00	54.55	45.45
	Libprotoident	13.64	0.00	86.36
	NBAR	0.00	0.00	100.00

5.4.3 Web Services

The most interesting observations are shown below:

- Only NDPI is able to recognize web services in this set. The detection rate is almost the same as for the normal set. Other classifiers tend to leave such traffic as *unknown*.

The following listing summarizes the classification results:

Web Service	Classifier	Correct [%]	Wrong [%]	Unclassified [%]
4Shared	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	88.78	11.22
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	65.31	34.69
	NDPI	0.00	81.63	18.37
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Amazon	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	70.43	29.57
	L7-filter-sel	0.00	4.65	95.35
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	37.54	62.46
	NDPI	0.00	34.72	65.28
	Libprotoident	0.00	0.83	99.17
	NBAR	0.00	0.00	100.00
Apple	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.0.00	79.04	20.96
	L7-filter-sel	0.00	0.84	99.16
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	5.45	94.55
	NDPI	1.26	52.20	46.54
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Ask	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	98.83	1.17
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	56.14	43.86
	NDPI	0.00	91.23	8.77
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Bing	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	94.52	5.48
	L7-filter-sel	0.00	0.88	99.12
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	7.02	92.98
	NDPI	0.00	37.50	62.50
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Blogspot	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	88.09	11.91
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	2.98	97.02
	NDPI	93.19	6.38	0.43
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	89.88	10.12
	L7-filter-sel	0.00	0.40	99.60

CNN	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	2.43	97.57
	NDPI	0.00	64.78	35.22
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	91.62	8.38
	L7-filter-sel	0.00	0.00	100.00
Craigslist	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	1.68	98.32
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	79.82	20.18
	L7-filter-sel	0.00	1.20	98.80
Cyworld	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	28.31	71.69
	NDPI	0.00	57.23	42.77
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.61	15.38
	L7-filter-sel	0.00	0.00	100.00
Doubleclick	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	13.88	86.12
	NDPI	95.12	3.02	1.86
	Libprotoident	0.00	0.05	99.95
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	70.11	29.89
	L7-filter-sel	0.00	1.42	98.58
eBay	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	24.91	75.09
	NDPI	0.00	5.34	94.66
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	81.17	18.83
	L7-filter-sel	0.00	9.42	90.58
Facebook	L7-filter-aut	0.00	0.20	99.80
	L7-filter-com	0.00	21.56	78.44
	NDPI	0.00	21.44	78.56
	Libprotoident	0.00	0.01	99.99
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.78	15.22
	L7-filter-sel	0.00	0.30	99.70
Go.com	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	11.34	86.66
	NDPI	0.00	32.54	67.46
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00

	L7-filter-all	0.00	68.34	31.66
	L7-filter-sel	0.00	0.76	99.24
Google	L7-filter-aut	0.00	0.37	99.63
	L7-filter-com	0.00	23.23	76.76
	NDPI	74.10	7.32	18.58
	Libprotoident	0.00	0.08	99.92
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	88.89	11.11
	L7-filter-sel	0.00	0.00	100.00
Instagram	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	11.11	88.89
	NDPI	0.00	66.67	33.33
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	88.05	11.95
	L7-filter-sel	0.00	15.26	84.74
Justin.tv	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	28.29	71.71
	NDPI	0.00	39.68	60.32
	Libprotoident	0.00	0.30	99.70
	NBAR	0.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	56.45	43.55
	L7-filter-sel	0.00	0.00	100.00
LinkedIn	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	6.45	93.55
	NDPI	0.00	54.84	45.16
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	30.51	69.49
	L7-filter-sel	0.00	0.21	99.79
Mediafire	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.66	95.34
	NDPI	0.00	98.94	1.06
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	75.75	24.25
	L7-filter-sel	0.00	5.28	94.72
MSN	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	19.29	80.71
	NDPI	0.00	38.04	61.96
	Libprotoident	0.00	0.22	99.78
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	0.00	100.00
Myspace	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	100.00	0.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00

	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.13	15.87
	L7-filter-sel	0.00	2.12	97.88
Pinterest	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	20.63	79.37
	NDPI	0.00	35.98	64.02
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	86.41	15.59
	L7-filter-sel	0.00	1.94	98.06
Putlocker	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	44.66	55.34
	NDPI	0.00	84.47	15.33
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	82.47	17.53
	L7-filter-sel	0.00	0.13	99.87
QQ.com	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	25.50	74.50
	NDPI	0.00	30.94	69.06
	Libprotoident	0.00	0.13	99.87
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	91.99	8.01
	L7-filter-sel	0.00	0.00	100.00
Taobao	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	5.17	94.83
	NDPI	0.00	43.93	56.07
	Libprotoident	0.00	0.26	99.74
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	94.37	5.63
The	L7-filter-sel	0.00	2.82	97.18
Huffington	L7-filter-aut	0.00	0.00	100.00
Post	L7-filter-com	0.00	19.72	80.28
	NDPI	0.00	14.08	85.92
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	88.34	11.66
	L7-filter-sel	0.00	1.24	98.76
Tumblr	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	7.44	92.56
	NDPI	0.00	16.87	83.13
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	52.11	47.89
	L7-filter-sel	0.00	9.40	90.60
Twitter	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	27.42	72.58
	NDPI	0.00	13.44	86.46

	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Vimeo	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	54.20	45.80
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.58	95.42
	NDPI	0.00	51.91	48.09
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Vk.com	PACE	0.00	0.00	0.00
	OpenDPI	0.00	0.00	0.00
	L7-filter-all	0.00	97.38	2.62
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	3.50	96.50
	NDPI	0.00	38.48	61.52
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Wikipedia	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	68.70	31.30
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.60	95.40
	NDPI	0.00	0.49	99.51
	Libprotoident	0.00	0.03	99.97
	NBAR	0.00	0.00	100.00
Windows Live	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	65.38	34.62
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	50.00	50.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Wordpress	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.62	15.38
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	8.88	91.12
	NDPI	0.00	26.04	73.96
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Yahoo	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	85.05	14.95
	L7-filter-sel	0.00	2.27	97.73
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	8.69	91.31
	NDPI	0.00	42.52	57.48
	Libprotoident	2.36	0.00	97.64
	NBAR	0.00	0.00	100.00
YouTube	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	82.64	17.36
	L7-filter-sel	0.00	0.51	99.49
	L7-filter-aut	0.00	0.24	99.76

L7-filter-com	0.00	11.92	88.08
NDPI	75.69	11.48	12.83
Libprotoident	0.00	0.00	100.00
NBAR	0.00	0.00	100.00

5.5 Evaluation on the Dataset with Truncated Flows

5.5.1 Application Protocols

The most interesting observations are shown below:

- Truncation of flows does not have any noticeable impact on the classification of application protocols.

The following listing summarizes the classification results:

Protocol	**Classifier**	**Correct** [%]	**Wrong** [%]	**Unclassified** [%]
DNS	PACE	99.95	0.00	0.05
	OpenDPI	99.99	0.00	0.01
	L7-filter-all	99.62	0.05	0.33
	L7-filter-sel	99.62	0.00	0.38
	L7-filter-aut	99.62	0.00	0.38
	L7-filter-com	99.62	0.02	0.36
	NDPI	99.99	0.00	0.01
	Libprotoident	99.96	0.00	0.04
	NBAR	99.98	0.01	0.01
HTTP	PACE	71.23	0.63	28.14
	OpenDPI	95.95	0.59	3.46
	L7-filter-all	3.58	96.04	0.38
	L7-filter-sel	39.21	1.98	58.81
	L7-filter-aut	34.38	0.41	65.21
	L7-filter-com	34.99	10.28	54.73
	NDPI	82.11	0.01	17.88
	Libprotoident	99.80	0.07	0.13
	NBAR	97.79	0.17	2.04
ICMP	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	99.02	0.00	0.98
IMAP STARTTLS	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
	L7-filter-aut	100.00	0.00	0.00
	L7-filter-com	100.00	0.00	0.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
IMAP TLS	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00

	NDPI	0.00	0.00	100.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	99.96	0.00	0.04
	OpenDPI	98.51	0.00	1.49
	L7-filter-all	0.00	5.63	94.37
NETBIOS	L7-filter-sel	0.00	0.00	100.00
Name	L7-filter-aut	0.00	0.00	100.00
Service	L7-filter-com	0.00	9.15	90.85
	NDPI	100.00	0.00	0.00
	Libprotoident	0.04	4.94	95.02
	NBAR	100.00	0.00	0.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	9.09	0.00	90.91
NETBIOS	L7-filter-sel	9.09	0.00	90.91
Session	L7-filter-aut	9.09	0.00	90.91
Service	L7-filter-com	9.09	0.00	90.91
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
SAMBA	L7-filter-sel	100.00	0.00	0.00
Session	L7-filter-aut	100.00	0.00	0.00
Service	L7-filter-com	100.00	0.00	0.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	99.86	0.14	0.00
	L7-filter-sel	0.00	0.08	99.92
NTP	L7-filter-aut	0.00	0.08	99.92
	L7-filter-com	99.86	0.13	0.01
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
POP3	L7-filter-aut	100.00	0.00	0.00
PLAIN	L7-filter-com	100.00	0.00	0.00
	NDPI	100.00	0.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	5.93	94.06
	L7-filter-sel	0.00	0.00	100.00
POP3	L7-filter-aut	0.00	0.00	100.00
TLS	L7-filter-com	0.00	0.99	99.01
	NDPI	0.01	0.00	99.99
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	23.54	76.46
	L7-filter-sel	0.00	0.53	99.47

RTMP	L7-filter-aut	0.00	0.26	99.74
	L7-filter-com	0.00	23.54	76.46
	NDPI	0.00	4.23	95.77
	Libprotoident	85.71	0.26	14.03
	NBAR	0.00	0.26	99.74
SMTP PLAIN	PACE	100.00	0.00	0.00
	OpenDPI	100.00	0.00	0.00
	L7-filter-all	100.00	0.00	0.00
	L7-filter-sel	100.00	0.00	0.00
	L7-filter-aut	100.00	0.00	0.00
	L7-filter-com	100.00	0.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	100.00	0.00	0.00
	NBAR	100.00	0.00	0.00
SMTP TLS	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	0.00	100.00
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
SOCKSv5	PACE	93.10	0.00	6.90
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	100.00	0.00
	L7-filter-aut	0.00	100.00	0.00
	L7-filter-com	0.00	100.00	0.00
	NDPI	0.00	100.00	0.00
	Libprotoident	100.00	0.00	0.00
	NBAR	0.00	0.00	100.00
SSH	PACE	93.98	0.51	5.51
	OpenDPI	93.98	0.12	5.90
	L7-filter-all	94.19	0.36	5.45
	L7-filter-sel	94.19	0.12	5.69
	L7-filter-aut	94.19	0.12	5.69
	L7-filter-com	94.19	0.12	5.69
	NDPI	93.98	0.14	5.88
	Libprotoident	94.19	0.36	5.45
	NBAR	93.72	0.60	5.68
Webdav	PACE	3.51	0.00	96.49
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	7.02	92.98
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	7.02	92.98
	NDPI	0.00	96.49	3.51
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00

5.5.2 Applications

The most interesting observations are shown below:

- Truncation of flows has small, but noticeable impact on the classification of applications – the detection rate decreases. The only exception is Libprotoident, which provides the same results as for the normal dataset.
- Plain eDonkey traffic is a very interesting group, as the best classification accuracy (45.28 %) we obtained

by using PACE on the set with truncated flows, while the accuracy on the normal set was only 16.50 %.

- FTP in the active mode is a very interesting case, as Libprotoident maintains its 100 % accuracy, while the accuracy of the other classifiers drops to 5.56 %.

The following listing summarizes the classification results:

Application	**Classifier**	**Correct [%]**	**Wrong [%]**	**Unclassified [%]**
4Shared	PACE	27.08	0.00	72.92
	OpenDPI	27.08	0.00	72.92
	L7-filter-all	0.00	1.39	98.61
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	72.92	27.08
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
America's Army	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	97.71	2.29
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	97.43	2.57
	NDPI	2.57	40.25	57.14
	Libprotoident	0.00	89.14	10.86
	NBAR	0.00	64.86	35.14
BitTorrent clients (encrypted)	PACE	66.60	0.04	33.36
	OpenDPI	0.27	0.00	99.73
	L7-filter-all	40.41	10.09	49.50
	L7-filter-sel	40.51	0.65	58.84
	L7-filter-aut	40.51	0.22	59.27
	L7-filter-com	40.49	7.22	52.29
	NDPI	53.82	23.68	22.50
	Libprotoident	60.31	0.02	39.67
	NBAR	1.02	0.19	98.79
BitTorrent clients (non-encrypted)	PACE	99.82	0.00	0.18
	OpenDPI	80.61	0.00	19.39
	L7-filter-all	94.48	0.47	5.05
	L7-filter-sel	94.51	0.06	5.43
	L7-filter-aut	94.51	0.06	5.43
	L7-filter-com	94.51	0.40	5.09
	NDPI	97.48	2.36	0.16
	Libprotoident	99.30	0.00	0.70
	NBAR	26.70	0.11	73.19
Dropbox	PACE	94.62	0.00	5.38
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	86.02	12.90	1.08
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
eDonkey clients (obfuscated)	PACE	35.34	5.34	59.32
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	11.64	16.59	71.77
	L7-filter-sel	0.00	0.10	99.90
	L7-filter-aut	0.00	0.02	99.98
	L7-filter-com	11.64	11.09	77.27
	NDPI	0.00	60.55	39.45

	Libprotoident	11.47	0.00	88.53
	NBAR	0.00	3.73	96.27
	PACE	45.28	2.55	52.17
	OpenDPI	3.96	0.30	95.74
	L7-filter-all	17.97	16.32	65.71
eDonkey	L7-filter-sel	0.04	0.39	99.57
clients	L7-filter-aut	0.04	0.31	99.65
(non-obfuscated)	L7-filter-com	17.99	10.79	71.22
	NDPI	2.17	54.69	43.14
	Libprotoident	17.86	0.31	81.83
	NBAR	1.32	5.94	92.74
	PACE	69.63	0.00	30.37
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	19.26	80.74
	L7-filter-sel	0.00	0.74	99.26
Freenet	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	13.33	86.67
	NDPI	0.00	15.56	84.44
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	15.56	84.44
	PACE	5.56	0.00	94.44
	OpenDPI	5.56	0.00	94.44
	L7-filter-all	5.56	92.06	2.38
FTP	L7-filter-sel	5.56	90.47	3.97
clients	L7-filter-aut	5.56	90.47	3.97
(active)	L7-filter-com	5.56	90.47	3.97
	NDPI	5.56	0.00	94.44
	Libprotoident	100.00	0.00	0.00
	NBAR	5.56	0.00	94.44
	PACE	4.92	0.00	95.08
	OpenDPI	4.92	0.00	95.08
	L7-filter-all	4.92	72.95	27.05
FTP	L7-filter-sel	4.92	71.31	28.69
clients	L7-filter-aut	4.92	71.31	28.69
(passive)	L7-filter-com	4.92	71.31	28.69
	NDPI	0.00	75.41	24.59
	Libprotoident	72.95	0.82	26.23
	NBAR	4.92	0.00	95.08
	PACE	77.45	0.00	22.55
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	63.83	6.81	29.36
	L7-filter-sel	63.83	0.00	36.17
iTunes	L7-filter-aut	63.83	0.00	36.17
	L7-filter-com	63.83	0.00	36.17
	NDPI	0.00	16.17	83.83
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	13.04	86.96
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	69.57	30.43
League	L7-filter-sel	0.00	0.00	100.00
of	L7-filter-aut	0.00	13.04	86.96
Legends	L7-filter-com	0.00	4.35	95.65
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	4.35	95.65
	NBAR	0.00	0.00	100.00
	PACE	99.45	0.39	0.16
	OpenDPI	99.23	0.54	0.23
	L7-filter-all	0.00	0.74	99.26
Pando	L7-filter-sel	0.00	0.39	99.61
Media	L7-filter-aut	0.00	0.39	99.61

Booster	L7-filter-com	0.00	0.55	99.45
	NDPI	0.00	0.41	99.59
	Libprotoident	99.26	0.41	0.33
	NBAR	0.00	0.36	99.64
PPLive	PACE	88.21	0.00	11.79
	OpenDPI	0.07	0.00	99.93
	L7-filter-all	0.00	56.03	43.97
	L7-filter-sel	0.00	7.95	92.05
	L7-filter-aut	0.00	0.07	99.93
	L7-filter-com	0.00	17.15	82.85
	NDPI	0.00	44.97	55.03
	Libprotoident	44.70	0.00	55.30
	NBAR	0.00	0.40	99.60
PPStream	PACE	79.32	0.00	20.68
	OpenDPI	0.79	0.00	99.21
	L7-filter-all	0.00	38.21	61.79
	L7-filter-sel	0.00	1.58	98.42
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	14.90	85.10
	NDPI	0.09	80.54	19.37
	Libprotoident	0.96	0.00	99.04
	NBAR	0.00	7.01	92.99
RDP clients	PACE	99.69	0.00	0.31
	OpenDPI	99.70	0.00	0.30
	L7-filter-all	0.00	92.20	7.80
	L7-filter-sel	0.00	0.01	99.99
	L7-filter-aut	0.00	0.01	99.99
	L7-filter-com	0.00	92.20	7.80
	NDPI	97.37	2.34	0.29
	Libprotoident	99.66	0.01	0.33
	NBAR	0.00	0.67	99.33
Skype (all)	PACE	83.33	5.10	11.57
	OpenDPI	38.45	0.37	61.18
	L7-filter-all	58.06	31.65	10.29
	L7-filter-sel	29.08	0.78	70.14
	L7-filter-aut	28.94	0.83	70.23
	L7-filter-com	61.37	24.62	14.01
	NDPI	99.36	0.64	0.00
	Libprotoident	88.75	0.00	11.25
	NBAR	70.10	3.72	26.18
Skype (audio)	PACE	100.00	0.00	0.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	85.71	14.29	0.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	100.00	0.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Skype (file transfer)	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	16.67	83.33
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	16.67	83.33
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00

	L7-filter-sel	0.00	0.00	100.00
Skype	L7-filter-aut	0.00	0.00	100.00
(video)	L7-filter-com	0.00	100.00	0.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	66.27	3.07	30.66
	OpenDPI	66.27	2.36	31.37
	L7-filter-all	0.00	99.06	0.94
	L7-filter-sel	0.00	4.48	95.52
Sopcast	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	74.76	25.24
	NDPI	66.27	5.19	28.54
	Libprotoident	46.70	0.24	53.06
	NBAR	0.00	0.00	100.00
	PACE	37.64	2.25	60.11
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	43.26	56.74
	L7-filter-sel	0.00	1.12	98.88
Spotify	L7-filter-aut	0.00	1.69	98.31
	L7-filter-com	0.00	10.11	89.89
	NDPI	0.56	47.75	51.69
	Libprotoident	0.56	0.00	99.44
	NBAR	0.00	0.56	99.44
	PACE	55.19	0.75	44.06
	OpenDPI	0.33	0.00	99.67
	L7-filter-all	0.00	65.89	34.11
	L7-filter-sel	0.00	0.00	100.00
Steam	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.73	95.27
	NDPI	0.25	43.82	55.93
	Libprotoident	75.85	0.00	24.15
	NBAR	0.00	0.58	99.42
	PACE	85.95	0.00	14.05
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	0.00	100.00
	L7-filter-sel	0.00	0.00	100.00
TOR	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	3.24	86.49	10.27
	Libprotoident	33.51	0.00	66.49
	NBAR	0.00	2.16	97.84
	PACE	27.27	0.00	72.73
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	86.36	13.64
World	L7-filter-sel	0.00	0.00	100.00
of	L7-filter-aut	0.00	0.00	100.00
Warcraft	L7-filter-com	0.00	22.73	77.27
	NDPI	13.64	4.55	81.81
	Libprotoident	13.64	0.00	86.36
	NBAR	0.00	0.00	100.00

5.5.3 Web Services

The most interesting observations are shown below:

- The percentage of correctly classified web services is usually the same or nearly the same as for the normal set.
- NDPI very often better recognizes web services on this set than on the normal set. It is the best visible

on Facebook – only 0.09 % of flows were recognized properly for the normal set, while 8.47 % for the set with truncated flows.

The following listing summarizes the classification results:

Web Service	Classifier	Correct [%]	Wrong [%]	Unclassified [%]
4Shared	PACE	84.69	0.00	15.31
	OpenDPI	83.67	0.00	16.33
	L7-filter-all	0.00	84.69	15.31
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	65.31	34.69
	NDPI	0.00	4.08	95.92
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Amazon	PACE	58.80	0.00	41.20
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	70.10	29.90
	L7-filter-sel	0.00	1.33	98.67
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	40.53	59.47
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.83	99.17
	NBAR	0.00	0.00	100.00
Apple	PACE	0.84	3.98	95.18
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.42	75.47	24.11
	L7-filter-sel	0.42	0.00	99.58
	L7-filter-aut	0.42	0.00	99.58
	L7-filter-com	0.42	5.87	93.71
	NDPI	2.52	0.21	97.27
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Ask	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	98.83	1.17
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	56.14	43.86
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Bing	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	94.08	5.92
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.88	99.12
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Blogspot	PACE	3.83	0.00	96.17
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	87.66	12.34
	L7-filter-sel	0.00	0.43	99.57
	L7-filter-aut	0.00	0.43	99.57
	L7-filter-com	0.00	2.98	97.02
	NDPI	93.19	1.70	5.11
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00

	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	89.88	10.12
	L7-filter-sel	0.00	0.40	99.60
CNN	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	2.43	97.57
	NDPI	0.00	10.53	89.47
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	91.62	8.38
	L7-filter-sel	0.00	0.00	100.00
Craigslist	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	1.68	98.32
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	79.82	20.18
	L7-filter-sel	0.00	1.20	98.80
Cyworld	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	28.31	71.69
	NDPI	0.00	6.93	93.07
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.46	15.54
	L7-filter-sel	0.00	0.00	100.00
Doubleclick	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	9.80	90.20
	NDPI	95.12	0.30	4.58
	Libprotoident	0.00	0.05	99.95
	NBAR	0.00	0.00	100.00
	PACE	67.97	0.00	32.03
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	70.11	29.89
	L7-filter-sel	0.00	0.00	100.00
eBay	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	1.42	98.58
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	80.79	0.00	19.21
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	76.99	23.01
	L7-filter-sel	0.00	0.01	99.99
Facebook	L7-filter-aut	78.17	0.00	21.83
	L7-filter-com	0.00	6.57	93.43
	NDPI	8.47	0.42	91.11
	Libprotoident	0.00	0.01	99.99
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	76.72	23.28
	L7-filter-sel	0.00	0.30	99.70
Go.com	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	11.34	86.66
	NDPI	0.00	2.39	97.61

	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Google	PACE	10.79	0.00	89.21
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	60.36	39.64
	L7-filter-sel	0.00	0.11	99.89
	L7-filter-aut	0.00	0.08	99.92
	L7-filter-com	0.00	17.66	82.34
	NDPI	77.16	2.52	20.32
	Libprotoident	0.00	0.08	99.92
	NBAR	0.00	0.00	100.00
Instagram	PACE	88.89	0.00	11.11
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	88.89	11.11
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	11.11	88.89
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Justin.tv	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	87.23	12.77
	L7-filter-sel	0.00	20.38	79.62
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	25.15	74.85
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.30	99.70
	NBAR	0.00	0.00	0.00
LinkedIn	PACE	77.42	0.00	22.58
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	48.39	51.61
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	3.23	96.77
	NDPI	0.00	33.87	66.13
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Mediafire	PACE	30.30	0.00	69.70
	OpenDPI	30.30	0.00	69.70
	L7-filter-all	0.00	30.08	69.92
	L7-filter-sel	0.00	0.21	99.79
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.45	95.55
	NDPI	0.00	69.07	30.93
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
MSN	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	75.54	24.46
	L7-filter-sel	0.00	0.32	99.68
	L7-filter-aut	0.00	0.32	99.68
	L7-filter-com	0.00	11.75	88.25
	NDPI	0.00	4.53	95.47
	Libprotoident	0.00	0.22	99.78
	NBAR	0.00	0.00	100.00
Myspace	PACE	100.00	0.00	0.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	100.00	0.00
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00

	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Pinterest	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	82.54	17.46
	L7-filter-sel	0.00	2.65	97.35
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	21.16	78.84
	NDPI	0.00	3.70	96.30
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Putlocker	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	73.79	26.21
	L7-filter-sel	0.00	1.94	98.06
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	33.98	67.02
	NDPI	0.00	1.94	98.06
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
QQ.com	PACE	32.14	0.00	67.86
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	63.61	36.39
	L7-filter-sel	0.00	0.13	99.87
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	9.43	90.57
	NDPI	0.00	2.79	97.21
	Libprotoident	0.00	0.13	99.87
	NBAR	0.00	0.00	100.00
Taobao	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	81.14	18.86
	L7-filter-sel	0.00	0.00	100.00
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	5.17	94.83
	NDPI	0.00	0.52	99.48
	Libprotoident	0.00	0.26	99.74
	NBAR	0.00	0.00	100.00
The Huffington Post	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	94.37	5.63
	L7-filter-sel	0.00	2.82	97.18
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	28.17	71.83
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
Tumblr	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	73.45	26.55
	L7-filter-sel	0.00	1.24	98.76
	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	6.20	93.80
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	71.18	0.00	28.82
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	52.46	47.54

	L7-filter-sel	0.00	11.25	88.75
Twitter	L7-filter-aut	48.68	0.00	51.32
	L7-filter-com	0.00	30.32	69.68
	NDPI	2.37	1.32	96.31
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	50.38	49.62
	L7-filter-sel	0.00	0.00	100.00
Vimeo	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	3.82	96.18
	NDPI	0.00	26.72	73.28
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	0.00
	OpenDPI	0.00	0.00	0.00
	L7-filter-all	0.00	97.38	2.62
	L7-filter-sel	0.00	0.00	100.00
Vk.com	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	3.50	96.50
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	68.70	31.30
	L7-filter-sel	0.00	0.02	99.98
Wikipedia	L7-filter-aut	0.00	0.02	99.98
	L7-filter-com	0.00	0.57	99.43
	NDPI	0.00	0.07	99.93
	Libprotoident	0.00	0.03	99.97
	NBAR	0.00	0.00	100.00
	PACE	96.15	0.00	3.85
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	65.38	34.62
Windows	L7-filter-sel	0.00	0.00	100.00
Live	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	0.00	100.00
	NDPI	0.00	0.00	100.00
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	0.00	0.00	100.00
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.62	15.38
	L7-filter-sel	0.00	0.00	100.00
Wordpress	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	8.28	91.72
	NDPI	0.00	0.59	99.41
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00
	PACE	54.68	0.17	45.15
	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	84.81	15.19
	L7-filter-sel	0.00	0.05	99.95
Yahoo	L7-filter-aut	0.00	0.00	100.00
	L7-filter-com	0.00	4.43	95.57
	NDPI	0.90	0.00	99.10
	Libprotoident	2.36	0.00	97.64
	NBAR	0.00	0.01	99.99
	PACE	71.55	0.00	28.45

	OpenDPI	0.00	0.00	100.00
	L7-filter-all	0.00	81.85	18.15
	L7-filter-sel	0.00	0.32	99.68
YouTube	L7-filter-aut	61.21	0.00	38.79
	L7-filter-com	0.00	7.66	92.34
	NDPI	77.58	0.24	22.18
	Libprotoident	0.00	0.00	100.00
	NBAR	0.00	0.00	100.00

Chapter 6

Conclusions

In this report, we presented a novel approach to test different classifiers of traffic in computer networks. There are several major contributions made to the research community:

1) We showed how to build an efficient testbed containing computers equipped with different operating systems and a virtual Cisco router.

2) We described our methodology of generating the network traffic in a realistic way.

3) We invented a way to collect all the traffic going through the network interfaces, group it into flows, add the process label taken from the system sockets, and send packets together with all the information to the server.

4) We showed how to create and manage a system (VBS Server), which needs to deal effectively with a large MySQL database.

5) The data collected by us are available to other researchers, so they can compare the accuracy of their classifiers on the same dataset, which was already used to compare the classifiers evaluated by us.

6) We compared the accuracy of PACE, OpenDPI, NDPI, Libprotoident, NBAR, and four different variants of L7-filter. The results are presented in the report.

As it is shown in the previous chapter, *PACE* is the best classifier for most of the studied classification groups. This high ranking is due to the ability of providing the results on many various levels. However, PACE is a commercial tool not accessible for all the research community. Among the available open-source tools, *Libprotoident* and *NDPI* reveal as the most reliable solutions. Surprisingly for us, Libprotoident achieves very good results without giving a noticeable number of false classifications by using the first four bytes of payload for each direction. Although NDPI is able to recognize many protocols and applications, it also gives a very significant number of misclassifications. On the other hand, *L7-filter* and *NBAR* perform poorly in classifying the traffic from our dataset.

We did not observe large differences between the classifications performed on the normal dataset and the set with truncated flows to maximum 10 packets. The set with truncated packets is usually much worse classified than the other sets by all tools except Libprotoident, which maintains the same accuracy. NDPI seems to false classify as Skype numerous flows from other protocols, applications, and services. We found that our modified version of L7-filter-com provides overall better results than the default L7-filter-all by increased number of correct classifications and greatly reduced rate of misclassifications (especially, regarding the web services).

Nonetheless, the previous conclusions are obviously tied to our dataset. Although we have tried our best to emulate the real behavior of the users, many applications, behaviors and configurations are not represented on it. Because of that it has some limitations that we discuss next:

- In our study, we have evaluated 17 well-known application protocols, 19 applications (including 4 in various configurations), and 34 web services. The results obtained from the different classifiers are directly related to those groups. Thus, the introduction of different groups could arise different outcomes.
- The traffic generated for building the dataset, although has been manually and realistically created, is artificial. The backbone traffic would carry different behaviors of the groups that are not fully represented in our dataset (e.g., P2P clients running on port 80). The performance of the tools studied should not be extrapolated from the current results. However, the artificially created traffic allowed us to publish the dataset with full packet payloads.
- The poor performance of NBAR and L7-filter might be affected by the characteristics of our dataset. Thus, the reliability of previous works based on them is not called into question. Different configurations [24, 33, 66] and different or older classification groups would probably produce different results.
- The classification levels have considerable impact on the results. For instance, classifying Facebook, Google or Twitter instead of HTTP is currently not possible for Libprotoident, however it is possible for NDPI and PACE.
- The amount of data available would also have impacted on the performance. The study presented in this paper is performed with full payload packets. However, in other works the traces are usually collected with a few bytes of data [27, 36, 71] (e.g., 96 bytes) in order to avoid packet loss, disk space, and privacy issues. For this scenario, it seems that Libprotoident is a more suitable solution, giving it only uses the first 4 bytes of every packet.
- The nature, distribution, and heterogeneity of the traffic would also impact the performance. The amount of classes detected by PACE is considerably bigger than detected by the rest of the classifiers, which makes PACE more suitable for heterogeneous scenarios. Also, PACE and NDPI are able to classify traffic in asymmetric scenarios.

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Appendix A

Normal Dataset – Detailed Results

This section presents the detailed insight into the classification results performed on the normal dataset. The correct results are makred in green, wrong in red, while the unclassified items are left in black.

A.1 Application Protocols

A.1.1 DNS

A) PACE

Class	No. of Flows
DNS:no_subprotocols:not_detected	18242
unknown:no_subprotocols:not_detected	6
unknown:no_subprotocols:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
DNS	18249
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
DNS	18182
UNKNOWN	60
FINGER	6
SKYPE_SUBTYPE_SKYPEOUT	2
EDONKEY_SUBTYPE_PLAIN	1

D) L7-filter-sel

Class	No. of Flows
DNS	18182
UNKNOWN	69

E) L7-filter-aut

Class	No. of Flows
DNS	18182
UNKNOWN	69

F) L7-filter-com

Class	No. of Flows
DNS	18182
UNKNOWN	66
SKYPE_SUBTYPE_SKYPEOUT	2
EDONKEY_SUBTYPE_PLAIN	1

G) NDPI

Class	No. of Flows
dns	18250
unknown	1

H) Libprotoident

Class	No. of Flows
DNS	18243
Unknown_UDP	7
Unknown_TCP	1

I) NBAR

Class	No. of Flows
dns	18250
unclassified	1

A.1.2 HTTP

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	19783
Yahoo:webmail:not_detected	9468
HTTP:generic:facebook	5423
HTTP:generic:not_yet_detected	1849
HTTP:generic:youtube	1643
HTTP:media:not_detected	699
PPLIVE:no_subprotocols:not_detected	567
HTTP:generic:twitter	555
FLASH:no_subprotocols:youtube	368
FLASH:no_subprotocols:not_detected	334
unknown:no_subprotocols:not_yet_detected	320
Steam:no_subprotocols:not_detected	279
BitTorrent:plain:not_detected	267
QQLive:no_subprotocols:not_detected	242
HTTP:generic:ebay	214
HTTP:generic:amazon_cloud	153
DirectDownloadLink:mediafire.com:not_detected	143
HTTP:generic:itunes	127
DirectDownloadLink:4shared.com:not_detected	122
HTTP:generic:amazon_shop	57
MEEBO:unknown:not_detected	52
Yahoo:unknown:not_detected	43
QUICKTIME:no_subprotocols:not_detected	31
HTTP:generic:linkedin	30
Pando:no_subprotocols:not_detected	30
QUICKTIME:no_subprotocols:itunes	28
WINDOWSMEDIA:no_subprotocols:windowsmedia	23
unknown:no_subprotocols:not_detected	23
HTTP:generic:hotmail_webmail	12
MPEG:no_subprotocols:facebook	10
QUICKTIME:no_subprotocols:youtube	9
MPEG:no_subprotocols:youtube	8
HTTP:generic:instagram	8
HTTP:video:youtube	7
HTTP:generic:gmail	7
HTTP:generic:windowsmedia	5
HTTP:generic:flickr	5
HTTP:generic:live_com	5
FLASH:no_subprotocols:facebook	4
Spotify:no_subprotocols:amazon_cloud	4
WINDOWSMEDIA:no_subprotocols:not_detected	4
Yahoo:webchat:not_detected	4
World of Warcraft:no_subprotocols:not_detected	3
MPEG:no_subprotocols:not_detected	3
eDonkey:plain:not_detected	3
PPSTREAM:no_subprotocols:not_detected	3
HTTP:generic:myspace	2
WebDAV:no_subprotocols:not_detected	2
WINDOWSMEDIA:no_subprotocols:youtube	1
OGG:no_subprotocols:facebook	1

B) OpenDPI

Class	No. of Flows
HTTP	41263
FLASH	712
UNKNOWN	487
DIRECT_DOWNLOAD_LINK	264
BITTORRENT	251
QUICKTIME	117
WINDOWSMEDIA	27
EDONKEY	3
MPEG	2
OGG	1

C) L7-filter-all

Class	No. of Flows
FINGER	36997
SKYPE_SUBTYPE_SKYPEOUT	3572
HTTP_SUBTYPE_UNKNOWN	1531
XUNLEI	790
ITUNES	152
SOULSEEK	53
HTTP_SUBTYPE_CACHEHIT	12
UNKNOWN	10
KUGOO	4
ARMAGETRON	3
EDONKEY_SUBTYPE_PLAIN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	25079
HTTP_SUBTYPE_UNKNOWN	14524
HTTP_SUBTYPE_CACHEHIT	2390
XUNLEI	790
ITUNES	152
HTTP_SUBTYPE_VIDEO	77
SOULSEEK	53
HTTP_SUBTYPE_CHACHEMISS	45
KUGOO	6
ARMAGETRON	4
HTTP_SUBTYPE_AUDIO	4
NBNS	1
PPLIVE	1
SOCKS	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	20357
HTTP_SUBTYPE_UNKNOWN	12401
FACEBOOK	5440
HTTP_SUBTYPE_CACHEHIT	2383
YOUTUBE	1564
TWITTER	554
ITUNES	152
BITTORRENT_SUBTYPE_PLAIN	120
SOULSEEK	53
HTTP_SUBTYPE_VIDEO	48
HTTP_SUBTYPE_CHACHEMISS	45
ARMAGETRON	4
HTTP_SUBTYPE_AUDIO	4
NBNS	1
SOCKS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	23339
HTTP_SUBTYPE_UNKNOWN	12722
SKYPE_SUBTYPE_SKYPEOUT	3576
HTTP_SUBTYPE_CACHEHIT	2354
XUNLEI	790
ITUNES	152
HTTP_SUBTYPE_VIDEO	77
SOULSEEK	53
HTTP_SUBTYPE_CHACHEMISS	44
KUGOO	6
ARMAGETRON	4
HTTP_SUBTYPE_AUDIO	4
EDONKEY_SUBTYPE_PLAIN	3
NBNS	1
PPLIVE	1
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
http	36428
google	6523
skype	141
http_connect	8
unknown	7
facebook	6
Apple	5
dropbox	4
edonkey	3
yahoo	1
youtube	1

H) Libprotoident

Class	No. of Flows
HTTP	42737
HTTP_NonStandard	303
SOCKS5	53
BitTorrent	26
Web_Junk	3
EMule	3
Unknown_TCP	1
HTTP_443	1

I) NBAR

Class	No. of Flows
http	42711
unclassified	338
secure-http	67
bittorrent	3
edonkey	3
h323	3
irc	2

A.1.3 ICMP

A) PACE

Class	No. of Flows
ICMP:no_subprotocols:not_detected	205

B) OpenDPI

Class	No. of Flows
ICMP	205

C) L7-filter-all

Class	No. of Flows
UNKNOWN	205

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	205

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	205

F) L7-filter-com

Class	No. of Flows
UNKNOWN	205

G) NDPI

Class	No. of Flows
icmp	205

H) Libprotoident

Class	No. of Flows
ICMP	205

I) NBAR

Class	No. of Flows
icmp	205

A.1.4 IMAP-STARTTLS

A) PACE

Class	No. of Flows
IMAP:no_subprotocols:not_detected	35

B) OpenDPI

Class	No. of Flows
MAIL_IMAP	35

C) L7-filter-all

Class	No. of Flows
MAIL_IMAP	35

D) L7-filter-sel

Class	No. of Flows
MAIL_IMAP	35

E) L7-filter-aut

Class	No. of Flows
MAIL_IMAP	35

F) L7-filter-com

Class	No. of Flows
MAIL_IMAP	35

G) NDPI

Class	No. of Flows
imap	35

H) Libprotoident

Class	No. of Flows
IMAP	35

I) NBAR

Class	No. of Flows
imap	35

A.1.5 IMAP-TLS

A) PACE

Class	No. of Flows
SSL:generic:gmail	103

B) OpenDPI

Class	No. of Flows
SSL	103

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

G) NDPI

Class	No. of Flows
google	103

H) Libprotoident

Class	No. of Flows
IMAPS	103

I) NBAR

Class	No. of Flows
secure-imap	103

A.1.6 NETBIOS Name Service

A) PACE

Class	No. of Flows
NETBIOS:no_subprotocols:not_detected	10195
unknown:no_subprotocols:not_yet_detected	3
unknown:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
NETBIOS	10047
UNKNOWN	152

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9265
SKYPE_SUBTYPE_SKYPEOUT	446
EDONKEY_SUBTYPE_PLAIN	258
NTP	118
RTP	111
FINGER	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	10199

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	10199

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9266
SKYPE_SUBTYPE_SKYPEOUT	446
EDONKEY_SUBTYPE_PLAIN	258
NTP	118
RTP	111

G) NDPI

Class	No. of Flows
netbios	10199

H) Libprotoident

Class	No. of Flows
Unknown_UDP	9691
RTP	502
NetBIOS_UDP	4
Kademlia	1
eMule_UDP	1

I) NBAR

Class	No. of Flows
netbios	10199

A.1.7 NETBIOS Session Service

A) PACE

Class	No. of Flows
NETBIOS:no_subprotocols:not_detected	11

B) OpenDPI

Class	No. of Flows
NETBIOS	11

C) L7-filter-all

Class	No. of Flows
UNKNOWN	10
SMB	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	10
SMB	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	10
SMB	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	10
SMB	1

G) NDPI

Class	No. of Flows
netbios	11

H) Libprotoident

Class	No. of Flows
NetBIOS	11

I) NBAR

Class	No. of Flows
netbios	11

A.1.8 SAMBA Session Service

A) PACE

Class	No. of Flows
SMB/CIFS:no_subprotocols:not_detected	42808

B) OpenDPI

Class	No. of Flows
SMB	42808

C) L7-filter-all

Class	No. of Flows
SMB	42807
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
SMB	42807
UNKNOWN	1

E) L7-filter-aut

Class	No. of Flows
SMB	42807
UNKNOWN	1

F) L7-filter-com

Class	No. of Flows
SMB	42807
UNKNOWN	1

G) NDPI

Class	No. of Flows
smb	42808

H) Libprotoident

Class	No. of Flows
SMB	42808

I) NBAR

Class	No. of Flows
unclassified	42806
pcanywhere	2

A.1.9 NTP

A) PACE

Class	No. of Flows
NTP:no_subprotocols:not_detected	42227

B) OpenDPI

Class	No. of Flows
NTP	42227

C) L7-filter-all

Class	No. of Flows
NTP	42166
EDONKEY_SUBTYPE_PLAIN	52
UNKNOWN	6
QQ	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	42195
QQ	32

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	42195
QQ	32

F) L7-filter-com

Class	No. of Flows
NTP	42166
EDONKEY_SUBTYPE_PLAIN	52
UNKNOWN	6
QQ	3

G) NDPI

Class	No. of Flows
ntp	42227

H) Libprotoident

Class	No. of Flows
NTP	42227

I) NBAR

Class	No. of Flows
unclassified	42227

A.1.10 POP3-PLAIN

A) PACE

Class	No. of Flows
POP:no_subprotocols:not_detected	26

B) OpenDPI

Class	No. of Flows
MAIL_POP	26

C) L7-filter-all

Class	No. of Flows
MAIL_POP	26

D) L7-filter-sel

Class	No. of Flows
MAIL_POP	26

E) L7-filter-aut

Class	No. of Flows
MAIL_POP	26

F) L7-filter-com

Class	No. of Flows
MAIL_POP	26

G) NDPI

Class	No. of Flows
pop	26

H) Libprotoident

Class	No. of Flows
POP3	26

I) NBAR

Class	No. of Flows
pop3	26

A.1.11 POP3-TLS

A) PACE

Class	No. of Flows
SSL:generic:not_detected	101

B) OpenDPI

Class	No. of Flows
SSL	101

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	95
FINGER	5
SKYPE_SUBTYPE_SKYPEOUT	1

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	95
UNKNOWN	6

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	95
UNKNOWN	6

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	95
UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	1

G) NDPI

Class	No. of Flows
ssl_no_cert	88
google	12
pops	1

H) Libprotoident

Class	No. of Flows
POP3S	101

I) NBAR

Class	No. of Flows
secure-pop3	101

A.1.12 RTMP

A) PACE

Class	No. of Flows
FLASH:no_subprotocols:not_detected	329
unknown:no_subprotocols:not_yet_detected	43
FLASH:no_subprotocols:not_yet_detected	6

B) OpenDPI

Class	No. of Flows
FLASH	335
UNKNOWN	43

C) L7-filter-all

Class	No. of Flows
UNKNOWN	289
SKYPE_SUBTYPE_SKYPEOUT	50
TSP	36
H323	1
PPLIVE	1
SKYPE_SUBTYPE_AUDIO	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	376
H323	1
PPLIVE	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	377
H323	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	289
SKYPE_SUBTYPE_SKYPEOUT	50
TSP	36
H323	1
PPLIVE	1
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
flash	320
unknown	42
H323	16

H) Libprotoident

Class	No. of Flows
RTMP	327
No_Payload	40
Unknown_TCP	8
SSL/TLS	2
BitTorrent	1

I) NBAR

Class	No. of Flows
unclassified	377
mgcp	1

A.1.13 SMTP-PLAIN

A) PACE

Class	No. of Flows
SMTP:no_subprotocols:not_detected	67

B) OpenDPI

Class	No. of Flows
MAIL_SMTP	67

C) L7-filter-all

Class	No. of Flows
MAIL_SMTP	67

D) L7-filter-sel

Class	No. of Flows
MAIL_SMTP	67

E) L7-filter-aut

Class	No. of Flows
MAIL_SMTP	67

F) L7-filter-com

Class	No. of Flows
MAIL_SMTP	67

G) NDPI

Class	No. of Flows
unknown	67

H) Libprotoident

Class	No. of Flows
SMTP	67

I) NBAR

Class	No. of Flows
smtp	67

A.1.14 SMTP-TLS

A) PACE

Class	No. of Flows
SSL:generic:gmail	50
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
SSL	52

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

G) NDPI

Class	No. of Flows
google	50
ssl_no_cert	2

H) Libprotoident

Class	No. of Flows
SMTP_Secure	52

I) NBAR

Class	No. of Flows
unclassified	52

A.1.15 SOCKSv5

A) PACE

Class	No. of Flows
Socks:socksv5:not_yet_detected	1508
unknown:no_subprotocols:not_yet_detected	132
SSL:generic:not_detected	76
BitTorrent:plain:not_detected	68
SSL:generic:facebook	51
Google:encrypted:not_detected	40
HTTP:generic:not_detected	13
SSL:generic:twitter	11
SPDY:ssl:facebook	10
SPDY:ssl:twitter	8
Google:encrypted:not_yet_detected	3
SPDY:ssl:not_detected	3
SSL:generic:not_yet_detected	2
BitTorrent:encrypted:not_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	1927

C) L7-filter-all

Class	No. of Flows
SOULSEEK	1927

D) L7-filter-sel

Class	No. of Flows
SOULSEEK	1927

E) L7-filter-aut

Class	No. of Flows
SOULSEEK	1927

F) L7-filter-com

Class	No. of Flows
SOULSEEK	1927

G) NDPI

Class	No. of Flows
skype	1927

H) Libprotoident

Class	No. of Flows
SOCKS5	1927

I) NBAR

Class	No. of Flows
unclassified	1927

A.1.16 SSH

A) PACE

Class	No. of Flows
SSH:no_subprotocols:not_detected	36615
unknown:no_subprotocols:not_yet_detected	2032
SSL:generic:not_detected	97
SSL:generic:facebook	68
Google:encrypted:not_detected	57
BitTorrent:plain:not_detected	47
SPDY:ssl:not_detected	14
SPDY:ssl:facebook	11
SSL:generic:twitter	8
SPDY:ssl:twitter	5
SSL:generic:not_yet_detected	4
unknown:no_subprotocols:facebook	1
unknown:no_subprotocols:not_detected	1
BitTorrent:encrypted:not_detected	1

B) OpenDPI

Class	No. of Flows
SSH	36615
UNKNOWN	2036
SSL	263
BITTORRENT	47

C) L7-filter-all

Class	No. of Flows
SSH	36697
UNKNOWN	1855
SSL_SUBTYPE_UNKOWN	256
FINGER	93
BITTORRENT_SUBTYPE_PLAIN	47
SSL_SUBTYPE_VALIDCERTSSL	12
NTP	1

D) L7-filter-sel

Class	No. of Flows
SSH	36697
UNKNOWN	1949
SSL_SUBTYPE_UNKOWN	256
BITTORRENT_SUBTYPE_PLAIN	47
SSL_SUBTYPE_VALIDCERTSSL	12

E) L7-filter-aut

Class	No. of Flows
SSH	36697
UNKNOWN	1949
SSL_SUBTYPE_UNKOWN	256
BITTORRENT_SUBTYPE_PLAIN	47
SSL_SUBTYPE_VALIDCERTSSL	12

F) L7-filter-com

Class	No. of Flows
SSH	36697
UNKNOWN	1948
SSL_SUBTYPE_UNKOWN	256
BITTORRENT_SUBTYPE_PLAIN	47
SSL_SUBTYPE_VALIDCERTSSL	12
NTP	1

G) NDPI

Class	No. of Flows
ssh	36615
unknown	2107
ssl_no_cert	173
bittorrent	47
ssl	12
skype	7

H) Libprotoident

Class	No. of Flows
SSH	36697
No_Payload	1851
HTTPS	272
HTTP	93
BitTorrent	47
Unknown_TCP	1

I) NBAR

Class	No. of Flows
ssh	36512
unclassified	1928
secure-http	272
h323	107
http	93
bittorrent	47
xwindows	1
socks	1

A.1.17 Webdav

A) PACE

Class	No. of Flows
SSL:generic:not_detected	55
WebDAV:no_subprotocols:not_detected	2

B) OpenDPI

Class	No. of Flows
SSL	55
HTTP	2

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	53
RTP	2
SKYPE_SUBTYPE_SKYPEOUT	2

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	55
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	55
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	53
RTP	2
SKYPE_SUBTYPE_SKYPEOUT	2

G) NDPI

Class	No. of Flows
skype	55
http_connect	2

H) Libprotoident

Class	No. of Flows
HTTPS	55
HTTP	2

I) NBAR

Class	No. of Flows
secure-http	55
http	2

A.2 Applications

A.2.1 4Shared

A) PACE

Class	No. of Flows
SSL:generic:not_detected	105
DirectDownloadLink:4shared.com:not_detected	39

B) OpenDPI

Class	No. of Flows
SSL	105
DIRECT_DOWNLOAD_LINK	39

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
HTTP_SUBTYPE_UNKNOWN	37
FINGER	2

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
HTTP_SUBTYPE_UNKNOWN	37
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
HTTP_SUBTYPE_UNKNOWN	37
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
HTTP_SUBTYPE_UNKNOWN	37
UNKNOWN	2

G) NDPI

Class	No. of Flows
skype	105
http	39

H) Libprotoident

Class	No. of Flows
HTTPS	105
HTTP	39

I) NBAR

Class	No. of Flows
secure-http	105
http	21
unclassified	18

A.2.2 America's Army

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	320
unknown:no_subprotocols:not_detected	30

B) OpenDPI

Class	No. of Flows
UNKNOWN	350

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	316
RTP	16
FINGER	8
UNKNOWN	8
NTP	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	350

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	350

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	323
RTP	16
UNKNOWN	9
NTP	2

G) NDPI

Class	No. of Flows
unknown	199
skype	141
TeamSpeak	9
rtcp	1

H) Libprotoident

Class	No. of Flows
Steam_UDP	284
Unknown_UDP	38
HalfLife	28

I) NBAR

Class	No. of Flows
rtp	251
unclassified	98
rtcp	1

A.2.3 BitTorrent clients (encrypted)

A) PACE

Class	No. of Flows
BitTorrent:plain:not_detected	32030
BitTorrent:uTP:not_detected	26345
unknown:no_subprotocols:not_yet_detected	20348
BitTorrent:encrypted:not_detected	17460
unknown:no_subprotocols:not_detected	155
eDonkey:encrypted:not_detected	50
DNS:no_subprotocols:not_detected	10
HTTP:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	96139
BITTORRENT	236
HTTP	14
DNS	10

C) L7-filter-all

Class	No. of Flows
UNKNOWN	47516
BITTORRENT_SUBTYPE_PLAIN	39037
SKYPE_SUBTYPE_SKYPEOUT	3392
FINGER	2879
NTP	1654
EDONKEY_SUBTYPE_PLAIN	817
KUGOO	406
SKYPE_SUBTYPE_AUDIO	263
QQ	234
RTP	138
SSL_SUBTYPE_UNKOWN	18
HTTP_SUBTYPE_UNKNOWN	15
TSP	13
DNS	10
NBNS	4
PPLIVE	2
SOULSEEK	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	56535
BITTORRENT_SUBTYPE_PLAIN	39062
KUGOO	425
QQ	246
HTTP_SUBTYPE_UNKNOWN	95
SSL_SUBTYPE_UNKOWN	18
DNS	10
NBNS	4
PPLIVE	3
SOULSEEK	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	56961
BITTORRENT_SUBTYPE_PLAIN	39124
QQ	246
HTTP_SUBTYPE_UNKNOWN	35
SSL_SUBTYPE_UNKOWN	18
DNS	10
NBNS	4
SOULSEEK	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	50205
BITTORRENT_SUBTYPE_PLAIN	39038
SKYPE_SUBTYPE_SKYPEOUT	3427
NTP	1693
EDONKEY_SUBTYPE_PLAIN	833
KUGOO	411
SKYPE_SUBTYPE_AUDIO	269
QQ	235
RTP	144
HTTP_SUBTYPE_UNKNOWN	95
SSL_SUBTYPE_UNKOWN	18
TSP	14
DNS	10
NBNS	4
PPLIVE	2
SOULSEEK	1

G) NDPI

Class	No. of Flows
bittorrent	51751
skype	22826
unknown	21686
http	126
dns	10

H) Libprotoident

Class	No. of Flows
BitTorrent_UDP	57987
Unknown_TCP	36876
Unknown_UDP	1289
HTTP_NonStandard	110
No_Payload	74
HTTP	16
BitTorrent	14
DNS	10
RTMP	7
Invalid_Bittorrent	6
Gnutella_UDP	6
Web_Junk	2
Mystery_8000	1
Xunlei	1

I) NBAR

Class	No. of Flows
unclassified	94552
bittorrent	1111
h323	586
http	123
dns	10
pcanywhere	4
edonkey	4
xwindows	3
skype	2
nfs	1
novadigm	1
rsvp	1
sqlserver	1

A.2.4 BitTorrent clients (non-encrypted)

A) PACE

Class	No. of Flows
BitTorrent:plain:not_detected	240409
BitTorrent:uTP:not_detected	20476
unknown:no_subprotocols:not_yet_detected	341
BitTorrent:encrypted:not_detected	268
DNS:no_subprotocols:not_detected	12
HTTP:generic:not_detected	9
unknown:no_subprotocols:not_detected	5
eDonkey:encrypted:not_detected	2
eDonkey:plain:not_detected	2
HTTP:generic:amazon_cloud	1
SSL:generic:amazon_cloud	1
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
BITTORRENT	210772
UNKNOWN	50712
HTTP	27
DNS	12
EDONKEY	2
SSL	2

C) L7-filter-all

Class	No. of Flows
BITTORRENT_SUBTYPE_PLAIN	247293
UNKNOWN	12935
SKYPE_SUBTYPE_SKYPEOUT	780
FINGER	178
QQ	177
SKYPE_SUBTYPE_AUDIO	61
NTP	42
HTTP_SUBTYPE_UNKNOWN	17
EDONKEY_SUBTYPE_PLAIN	16
DNS	12
KUGOO	10
SSL_SUBTYPE_UNKOWN	2
STUN	2
RTP	1
SOCKS	1

D) L7-filter-sel

Class	No. of Flows
BITTORRENT_SUBTYPE_PLAIN	247312
UNKNOWN	13904
QQ	184
HTTP_SUBTYPE_UNKNOWN	100
DNS	12
KUGOO	10
SSL_SUBTYPE_UNKOWN	2
STUN	2
SOCKS	1

E) L7-filter-aut

Class	No. of Flows
BITTORRENT_SUBTYPE_PLAIN	247370
UNKNOWN	13905
QQ	184
HTTP_SUBTYPE_UNKNOWN	51
DNS	12
SSL_SUBTYPE_UNKOWN	2
STUN	2
SOCKS	1

F) L7-filter-com

Class	No. of Flows
BITTORRENT_SUBTYPE_PLAIN	247293
UNKNOWN	13029
SKYPE_SUBTYPE_SKYPEOUT	780
QQ	179
HTTP_SUBTYPE_UNKNOWN	99
SKYPE_SUBTYPE_AUDIO	61
NTP	42
EDONKEY_SUBTYPE_PLAIN	16
DNS	12
KUGOO	10
SSL_SUBTYPE_UNKOWN	2
STUN	2
RTP	1
SOCKS	1

G) NDPI

Class	No. of Flows
bittorrent	254786
skype	6170
unknown	407
http	147
dns	12
ssl_no_cert	2
edonkey	2
google	1

H) Libprotoident

Class	No. of Flows
BitTorrent	210603
BitTorrent_UDP	48847
Unknown_UDP	965
Unknown_TCP	669
No_Payload	192
HTTP_NonStandard	114
Invalid_Bittorrent	78
HTTP	34
DNS	12
Gnutella_UDP	9
HTTPS	2
EMule	2

I) NBAR

Class	No. of Flows
bittorrent	203402
unclassified	57005
h323	946
http	145
dns	12
ftp	7
secure-http	2
xwindows	2
cuseeme	2
edonkey	2
nfs	1
rsvp	1

A.2.5 Dropbox

A) PACE

Class	No. of Flows
SSL:generic:dropbox	88
HTTP:generic:not_detected	4
unknown:no_subprotocols:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
SSL	88
HTTP	4
UNKNOWN	1

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	60
SSL_SUBTYPE_VALIDCERTSSL	29
FINGER	4

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	60
SSL_SUBTYPE_VALIDCERTSSL	29
HTTP_SUBTYPE_UNKNOWN	2
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	60
SSL_SUBTYPE_VALIDCERTSSL	29
HTTP_SUBTYPE_UNKNOWN	2
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	60
SSL_SUBTYPE_VALIDCERTSSL	29
HTTP_SUBTYPE_UNKNOWN	2
UNKNOWN	2

G) NDPI

Class	No. of Flows
dropbox	80
skype	12
ssl_no_cert	1

H) Libprotoident

Class	No. of Flows
HTTPS	89
HTTP	4

I) NBAR

Class	No. of Flows
secure-http	89
http	4

A.2.6 eDonkey clients (obfuscated)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	7142
eDonkey:plain:not_detected	4613
BitTorrent:encrypted:not_detected	932
unknown:no_subprotocols:not_detected	133
eDonkey:encrypted:not_detected	15

B) OpenDPI

Class	No. of Flows
UNKNOWN	12835

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9212
EDONKEY_SUBTYPE_PLAIN	1494
FINGER	729
NTP	656
SKYPE_SUBTYPE_SKYPEOUT	615
SKYPE_SUBTYPE_AUDIO	74
RTP	38
KUGOO	11
TSP	4
QQ	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	12822
KUGOO	11
QQ	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	12833
QQ	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9917
EDONKEY_SUBTYPE_PLAIN	1494
NTP	670
SKYPE_SUBTYPE_SKYPEOUT	623
SKYPE_SUBTYPE_AUDIO	76
RTP	38
KUGOO	11
TSP	4
QQ	2

G) NDPI

Class	No. of Flows
skype	7587
unknown	5064
rtp	184

H) Libprotoident

Class	No. of Flows
Unknown_UDP	10387
eMule_UDP	1472
Unknown_TCP	976

I) NBAR

Class	No. of Flows
unclassified	10790
rtp	1789
rtcp	205
skype	41
secure-nntp	9
cuseeme	1

A.2.7 eDonkey clients (non-obfuscated)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	11024
eDonkey:plain:not_detected	2269
BitTorrent:encrypted:not_detected	474
BitTorrent:plain:not_detected	42
unknown:no_subprotocols:not_detected	25
HTTP:generic:not_detected	8
eDonkey:encrypted:not_detected	8
Google:encrypted:not_detected	1
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	13259
EDONKEY	543
BITTORRENT	42
HTTP	6
SSL	2

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9102
EDONKEY_SUBTYPE_PLAIN	2487
FINGER	793
NTP	677
SKYPE_SUBTYPE_SKYPEOUT	642
SKYPE_SUBTYPE_AUDIO	61
BITTORRENT_SUBTYPE_PLAIN	42
RTP	24
TSP	10
KUGOO	10
SSL_SUBTYPE_UNKOWN	2
QQ	1
STUN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	13793
BITTORRENT_SUBTYPE_PLAIN	42
KUGOO	10
HTTP_SUBTYPE_UNKNOWN	3
SSL_SUBTYPE_UNKOWN	2
STUN	1
QQ	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	13803
BITTORRENT_SUBTYPE_PLAIN	42
HTTP_SUBTYPE_UNKNOWN	3
SSL_SUBTYPE_UNKOWN	2
QQ	1
STUN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9865
EDONKEY_SUBTYPE_PLAIN	2487
NTP	693
SKYPE_SUBTYPE_SKYPEOUT	652
SKYPE_SUBTYPE_AUDIO	61
BITTORRENT_SUBTYPE_PLAIN	42
RTP	25
TSP	10
KUGOO	10
HTTP_SUBTYPE_UNKNOWN	3
SSL_SUBTYPE_UNKOWN	2
QQ	1
STUN	1

G) NDPI

Class	No. of Flows
skype	7413
unknown	5976
edonkey	294
rtp	118
bittorrent	42
http	6
ssl_no_cert	1
H323	1
google	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	10838
eMule_UDP	1893
EMule	571
Unknown_TCP	495
BitTorrent	42
HTTP	8
HTTPS	2
No_Payload	2
Skype	1

I) NBAR

Class	No. of Flows
unclassified	12018
rtp	1249
edonkey	274
rtcp	200
bittorrent	42
skype	41
h323	8
http	8
cuseeme	6
secure-nntp	3
secure-http	2
xwindows	1

A.2.8 Freenet

A) PACE

Class	No. of Flows
Freenet:no_subprotocols:not_detected	107
unknown:no_subprotocols:not_detected	15
unknown:no_subprotocols:not_yet_detected	13

B) OpenDPI

Class	No. of Flows
UNKNOWN	135

C) L7-filter-all

Class	No. of Flows
UNKNOWN	108
FINGER	9
SKYPE_SUBTYPE_SKYPEOUT	8
NTP	6
SKYPE_SUBTYPE_AUDIO	1
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
PPLIVE	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	132
KUGOO	1
PPLIVE	1
QQ	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	134
QQ	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	116
SKYPE_SUBTYPE_SKYPEOUT	9
NTP	6
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
PPLIVE	1
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
unknown	114
skype	20
rtp	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	135

I) NBAR

Class	No. of Flows
unclassified	114
rtp	16
skype	3
rtcp	2

A.2.9 FTP clients (active)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_detected	117
FTP:control:not_detected	7
unknown:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
FTP	123
UNKNOWN	3

C) L7-filter-all

Class	No. of Flows
SOCKS	113
FTP_SUBTYPE_CONTROL	7
UNKNOWN	3
FINGER	2
SKYPE_SUBTYPE_SKYPEOUT	1

D) L7-filter-sel

Class	No. of Flows
SOCKS	114
FTP_SUBTYPE_CONTROL	7
UNKNOWN	5

E) L7-filter-aut

Class	No. of Flows
SOCKS	114
FTP_SUBTYPE_CONTROL	7
UNKNOWN	5

F) L7-filter-com

Class	No. of Flows
SOCKS	113
FTP_SUBTYPE_CONTROL	7
UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	1

G) NDPI

Class	No. of Flows
ftp	123
unknown	3

H) Libprotoident

Class	No. of Flows
FTP_Data	119
FTP_Control	7

I) NBAR

Class	No. of Flows
ftp	64
unclassified	62

A.2.10 FTP clients (passive)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_detected	87
unknown:no_subprotocols:not_yet_detected	29
FTP:control:not_detected	6

B) OpenDPI

Class	No. of Flows
FTP	82
UNKNOWN	40

C) L7-filter-all

Class	No. of Flows
SOCKS	80
UNKNOWN	29
FTP_SUBTYPE_CONTROL	6
FINGER	3
NTP	2
PPLIVE	1
SKYPE_SUBTYPE_SKYPEOUT	1

D) L7-filter-sel

Class	No. of Flows
SOCKS	81
UNKNOWN	34
FTP_SUBTYPE_CONTROL	6
PPLIVE	1

E) L7-filter-aut

Class	No. of Flows
SOCKS	81
UNKNOWN	35
FTP_SUBTYPE_CONTROL	6

F) L7-filter-com

Class	No. of Flows
SOCKS	80
UNKNOWN	32
FTP_SUBTYPE_CONTROL	6
NTP	2
PPLIVE	1
SKYPE_SUBTYPE_SKYPEOUT	1

G) NDPI

Class	No. of Flows
skype	120
unknown	2

H) Libprotoident

Class	No. of Flows
FTP_Data	84
BitTorrent	28
FTP_Control	6
No_Payload	2
Unknown_TCP	2

I) NBAR

Class	No. of Flows
ftp	61
unclassified	61

A.2.11 iTunes

A) PACE

Class	No. of Flows
HTTP:generic:itunes	125
SSL:generic:not_detected	38
SSL:generic:itunes	31
QUICKTIME:no_subprotocols:itunes	26
QUICKTIME:no_subprotocols:not_detected	15

B) OpenDPI

Class	No. of Flows
HTTP	150
SSL	69
QUICKTIME	16

C) L7-filter-all

Class	No. of Flows
ITUNES	150
SSL_SUBTYPE_UNKOWN	38
SSL_SUBTYPE_VALIDCERTSSL	31
FINGER	16

D) L7-filter-sel

Class	No. of Flows
ITUNES	150
SSL_SUBTYPE_UNKOWN	38
SSL_SUBTYPE_VALIDCERTSSL	31
UNKNOWN	16

E) L7-filter-aut

Class	No. of Flows
ITUNES	150
SSL_SUBTYPE_UNKOWN	38
SSL_SUBTYPE_VALIDCERTSSL	31
UNKNOWN	16

F) L7-filter-com

Class	No. of Flows
ITUNES	150
SSL_SUBTYPE_UNKOWN	38
SSL_SUBTYPE_VALIDCERTSSL	31
UNKNOWN	16

G) NDPI

Class	No. of Flows
http	166
skype	38
ssl_no_cert	31

H) Libprotoident

Class	No. of Flows
HTTP	166
HTTPS	69

I) NBAR

Class	No. of Flows
http	166
secure-http	69

A.2.12 League of Legends

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	12
SSL:generic:not_detected	5
FLASH:no_subprotocols:youtube	2
unknown:no_subprotocols:not_detected	2
HTTP:generic:youtube	1
FLASH:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	14
SSL	5
FLASH	2
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
FINGER	15
SSL_SUBTYPE_UNKOWN	4
UNKNOWN	2
HTTP_SUBTYPE_UNKNOWN	1
RTP	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	13
HTTP_SUBTYPE_UNKNOWN	5
SSL_SUBTYPE_UNKOWN	5

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	10
HTTP_SUBTYPE_UNKNOWN	5
SSL_SUBTYPE_UNKOWN	5
YOUTUBE	3

F) L7-filter-com

Class	No. of Flows
UNKNOWN	13
HTTP_SUBTYPE_UNKNOWN	5
SSL_SUBTYPE_UNKOWN	4
RTP	1

G) NDPI

Class	No. of Flows
http	16
ssl_no_cert	3
ssl	2
unknown	2

H) Libprotoident

Class	No. of Flows
HTTP	16
HTTPS	3
Unknown_UDP	2
ApplePush	1
SSL/TLS	1

I) NBAR

Class	No. of Flows
http	16
unclassified	4
secure-http	3

A.2.13 Pando Media Booster

A) PACE

Class	No. of Flows
Pando:no_subprotocols:not_detected	13379
BitTorrent:plain:not_detected	53
unknown:no_subprotocols:not_yet_detected	17
SSL:generic:not_detected	2
STUN:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
PANDO	13349
BITTORRENT	71
UNKNOWN	17
HTTP	12
SSL	2
STUN	2

C) L7-filter-all

Class	No. of Flows
UNKNOWN	13345
BITTORRENT_SUBTYPE_PLAIN	53
FINGER	25
TSP	17
HTTP_SUBTYPE_UNKNOWN	9
RTP	2
SKYPE_SUBTYPE_SKYPEOUT	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	13375
BITTORRENT_SUBTYPE_PLAIN	53
HTTP_SUBTYPE_UNKNOWN	24
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	13375
BITTORRENT_SUBTYPE_PLAIN	53
HTTP_SUBTYPE_UNKNOWN	24
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	13355
BITTORRENT_SUBTYPE_PLAIN	53
HTTP_SUBTYPE_UNKNOWN	24
TSP	17
RTP	2
SKYPE_SUBTYPE_SKYPEOUT	2

G) NDPI

Class	No. of Flows
unknown	13366
bittorrent	53
http	30
ssl_no_cert	2
stun	2

H) Libprotoident

Class	No. of Flows
Pando	13331
BitTorrent	53
HTTP	28
Pando_UDP	22
No_Payload	13
STUN	2
HTTP_NonStandard	2
SSL/TLS	2

I) NBAR

Class	No. of Flows
unclassified	13375
http	30
bittorrent	28
h323	13
mgcp	3
sap	1
fasttrack	1
notes	1
pptp	1

A.2.14 PPLive

A) PACE

Class	No. of Flows
PPLIVE:no_subprotocols:not_detected	1332
HTTP:generic:not_detected	110
HTTP:generic:not_yet_detected	46
unknown:no_subprotocols:not_yet_detected	19
STUN:no_subprotocols:not_yet_detected	2
unknown:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	784
HTTP	657
QUICKTIME	65
STUN	2
FLASH	1
PPLIVE	1

C) L7-filter-all

Class	No. of Flows
UNKNOWN	663
FINGER	588
XUNLEI	108
SKYPE_SUBTYPE_SKYPEOUT	99
NTP	23
KUGOO	11
EDONKEY_SUBTYPE_PLAIN	8
SKYPE_SUBTYPE_AUDIO	7
HTTP_SUBTYPE_UNKNOWN	1
NBNS	1
RTP	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1359
XUNLEI	108
HTTP_SUBTYPE_UNKNOWN	31
KUGOO	11
NBNS	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1473
HTTP_SUBTYPE_UNKNOWN	36
NBNS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	1230
XUNLEI	108
SKYPE_SUBTYPE_SKYPEOUT	100
NTP	23
HTTP_SUBTYPE_UNKNOWN	21
KUGOO	11
EDONKEY_SUBTYPE_PLAIN	8
SKYPE_SUBTYPE_AUDIO	7
NBNS	1
RTP	1

G) NDPI

Class	No. of Flows
http	723
skype	674
unknown	108
rtp	2
stun	2
Viber	1

H) Libprotoident

Class	No. of Flows
HTTP	723
PPLive	675
Unknown_UDP	109
STUN	2
No_Payload	1

I) NBAR

Class	No. of Flows
unclassified	783
http	721
rtcp	5
novadigm	1

A.2.15 PPStream

A) PACE

Class	No. of Flows
PPSTREAM:no_subprotocols:not_detected	905
unknown:no_subprotocols:not_yet_detected	116
HTTP:generic:not_yet_detected	79
HTTP:generic:not_detected	31
FLASH:no_subprotocols:not_detected	6
unknown:no_subprotocols:not_detected	4

B) OpenDPI

Class	No. of Flows
UNKNOWN	1013
HTTP	113
PPSTREAM	9
FLASH	6

C) L7-filter-all

Class	No. of Flows
UNKNOWN	703
FINGER	266
SKYPE_SUBTYPE_SKYPEOUT	90
NTP	35
TSP	28
XUNLEI	18
NBNS	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1104
HTTP_SUBTYPE_UNKNOWN	18
XUNLEI	18
NBNS	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1122
HTTP_SUBTYPE_UNKNOWN	18
NBNS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	958
SKYPE_SUBTYPE_SKYPEOUT	90
NTP	35
TSP	28
XUNLEI	18
HTTP_SUBTYPE_UNKNOWN	11
NBNS	1

G) NDPI

Class	No. of Flows
skype	918
http	119
unknown	102
Viber	1
ppstream	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	1011
HTTP	119
PPStream	11

I) NBAR

Class	No. of Flows
unclassified	962
http	119
rtp	60

A.2.16 RDP clients

A) PACE

Class	No. of Flows
RDP:no_subprotocols:not_detected	153357
unknown:no_subprotocols:not_yet_detected	480

B) OpenDPI

Class	No. of Flows
RDP	153369
UNKNOWN	468

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	141908
UNKNOWN	11918
NBNS	10
PPLIVE	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	153815
NBNS	17
PPLIVE	3
ARMAGETRON	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	153818
NBNS	17
ARMAGETRON	2

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	141908
UNKNOWN	11918
NBNS	10
PPLIVE	1

G) NDPI

Class	No. of Flows
rdp	149798
skype	3571
unknown	445
H323	23

H) Libprotoident

Class	No. of Flows
RDP	153312
No_Payload	451
Unknown_TCP	57
BitTorrent	10
RTMP	7

I) NBAR

Class	No. of Flows
unclassified	152804
h323	336
novadigm	117
citrix	115
skinny	86
mgcp	85
sap	81
notes	34
l2tp	33
nfs	33
sqlnet	29
socks	28
pptp	21
fasttrack	21
sqlserver	11
vdolive	2
pcanywhere	1

A.2.17 Skype

A) PACE

Class	No. of Flows
Skype:unknown:not_detected	1126
SSL:generic:not_detected	485
unknown:no_subprotocols:not_yet_detected	174
HTTP:generic:not_detected	94
SSL:generic:facebook	90
unknown:no_subprotocols:not_detected	75
HTTP:generic:not_yet_detected	34
Skype:unknown:live_com	33
Skype:voice:not_detected	25
Google:encrypted:not_detected	12
Skype:video:not_detected	12
Skype:out:not_detected	9
FLASH:no_subprotocols:youtube	5
FLASH:no_subprotocols:not_detected	2
HTTP:generic:youtube	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	1332
SSL	709
HTTP	129
FLASH	7

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	1040
RTP	468
SSL_SUBTYPE_UNKOWN	242
UNKNOWN	198
FINGER	154
EDONKEY_SUBTYPE_PLAIN	35
NTP	23
SKYPE_SUBTYPE_SKYPEOUT	7
QQ	7
KUGOO	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1384
SSL_SUBTYPE_UNKOWN	702
HTTP_SUBTYPE_UNKNOWN	71
QQ	14
KUGOO	5
HTTP_SUBTYPE_VIDEO	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1386
SSL_SUBTYPE_UNKOWN	702
HTTP_SUBTYPE_UNKNOWN	68
QQ	14
YOUTUBE	6
HTTP_SUBTYPE_VIDEO	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	1041
RTP	468
UNKNOWN	279
SSL_SUBTYPE_UNKOWN	242
HTTP_SUBTYPE_UNKNOWN	71
EDONKEY_SUBTYPE_PLAIN	35
NTP	23
SKYPE_SUBTYPE_SKYPEOUT	7
QQ	7
KUGOO	3
HTTP_SUBTYPE_VIDEO	1

G) NDPI

Class	No. of Flows
skype	1589
ssl_no_cert	303
ssl	137
http	134
google	14

H) Libprotoident

Class	No. of Flows
Skype	1086
HTTPS	709
Unknown_TCP	232
HTTP	136
Unknown_UDP	13
SSL/TLS	1

I) NBAR

Class	No. of Flows
secure-http	706
skype	690
unclassified	571
http	136
rtp	63
rtcp	5
novadigm	4
h323	2

A.2.18 Skype (audio)

A) PACE

Class	No. of Flows
Skype:voice:not_detected	7

B) OpenDPI

Class	No. of Flows
UNKNOWN	7

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	6
FINGER	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	7

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	7

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

G) NDPI

Class	No. of Flows
skype	7

H) Libprotoident

Class	No. of Flows
Unknown_UDP	4
Skype	3

I) NBAR

Class	No. of Flows
skype	7

A.2.19 Skype (file transfer)

A) PACE

Class	No. of Flows
Skype:voice:not_detected	6

B) OpenDPI

Class	No. of Flows
UNKNOWN	6

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	5
QQ	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	5
QQ	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	5
QQ	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	5
QQ	1

G) NDPI

Class	No. of Flows
skype	6

H) Libprotoident

Class	No. of Flows
Unknown_UDP	5
Skype	1

I) NBAR

Class	No. of Flows
skype	6

A.2.20 Skype (video)

A) PACE

Class	No. of Flows
Skype:voice:not_detected	7

B) OpenDPI

Class	No. of Flows
UNKNOWN	7

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	6
QQ	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	6
QQ	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

G) NDPI

Class	No. of Flows
skype	7

H) Libprotoident

Class	No. of Flows
Skype	6
Unknown_UDP	1

I) NBAR

Class	No. of Flows
skype	7

A.2.21 Sopcast

A) PACE

Class	No. of Flows
SOPCAST:no_subprotocols:not_detected	281
HTTP:generic:not_detected	112
Yahoo:webmail:not_detected	12
FLASH:no_subprotocols:not_detected	11
HTTP:generic:not_yet_detected	4
unknown:no_subprotocols:not_yet_detected	3
SSL:generic:facebook	1

B) OpenDPI

Class	No. of Flows
SOPCAST	281
HTTP	128
FLASH	11
UNKNOWN	3
SSL	1

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	291
FINGER	103
XUNLEI	19
TSP	6
UNKNOWN	3
SKYPE_SUBTYPE_AUDIO	1
SSL_SUBTYPE_UNKOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	397
XUNLEI	19
HTTP_SUBTYPE_UNKNOWN	5
HTTP_SUBTYPE_CHACHEMISS	1
PPLIVE	1
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	417
HTTP_SUBTYPE_UNKNOWN	5
HTTP_SUBTYPE_CHACHEMISS	1
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	291
UNKNOWN	100
XUNLEI	19
TSP	6
HTTP_SUBTYPE_UNKNOWN	5
HTTP_SUBTYPE_CHACHEMISS	1
SKYPE_SUBTYPE_AUDIO	1
SSL_SUBTYPE_UNKOWN	1

G) NDPI

Class	No. of Flows
sopcast	281
http	121
google	18
skype	4

H) Libprotoident

Class	No. of Flows
Sopcast	198
HTTP	139
Unknown_UDP	82
Unknown_TCP	3
HTTPS	1
Skype	1

I) NBAR

Class	No. of Flows
unclassified	284
http	139
secure-http	1

A.2.22 Spotify

A) PACE

Class	No. of Flows
Spotify:no_subprotocols:not_detected	63
HTTP:generic:not_detected	56
unknown:no_subprotocols:not_yet_detected	25
unknown:no_subprotocols:not_detected	17
SSL:generic:amazon_cloud	6
Spotify:no_subprotocols:amazon_cloud	4
HTTP:generic:facebook	3
SSL:generic:not_detected	2
HTTP:generic:not_yet_detected	1
SSL:generic:facebook	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	105
HTTP	64
SSL	9

C) L7-filter-all

Class	No. of Flows
UNKNOWN	92
FINGER	59
SSL_SUBTYPE_UNKOWN	9
SKYPE_SUBTYPE_SKYPEOUT	8
NTP	5
TSP	1
XUNLEI	1
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
RTP	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	163
SSL_SUBTYPE_UNKOWN	9
HTTP_SUBTYPE_UNKNOWN	3
HTTP_SUBTYPE_CACHEHIT	1
KUGOO	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	162
SSL_SUBTYPE_UNKOWN	9
FACEBOOK	3
HTTP_SUBTYPE_UNKNOWN	3
HTTP_SUBTYPE_CACHEHIT	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	147
SSL_SUBTYPE_UNKOWN	9
SKYPE_SUBTYPE_SKYPEOUT	8
NTP	5
HTTP_SUBTYPE_UNKNOWN	3
TSP	1
XUNLEI	1
EDONKEY_SUBTYPE_PLAIN	1
HTTP_SUBTYPE_CACHEHIT	1
KUGOO	1
RTP	1

G) NDPI

Class	No. of Flows
skype	85
http	64
unknown	22
ssl_no_cert	6
Spotify	1

H) Libprotoident

Class	No. of Flows
Unknown_TCP	100
HTTP	64
HTTPS	9
No_Payload	4
Spotify	1

I) NBAR

Class	No. of Flows
unclassified	104
http	64
secure-http	9
h323	1

A.2.23 Steam

A) PACE

Class	No. of Flows
Steam:no_subprotocols:not_detected	665
unknown:no_subprotocols:not_yet_detected	528
SSL:generic:windows_azure	6
SSL:generic:amazon_cloud	3
unknown:no_subprotocols:not_detected	2
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	916
HTTP	279
SSL	6
STEAM	4

C) L7-filter-all

Class	No. of Flows
FINGER	744
UNKNOWN	402
SKYPE_SUBTYPE_SKYPEOUT	48
SSL_SUBTYPE_UNKOWN	7
HTTP_SUBTYPE_UNKNOWN	2
NTP	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1014
HTTP_SUBTYPE_UNKNOWN	181
SSL_SUBTYPE_UNKOWN	10

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1014
HTTP_SUBTYPE_UNKNOWN	181
SSL_SUBTYPE_UNKOWN	10

F) L7-filter-com

Class	No. of Flows
UNKNOWN	972
HTTP_SUBTYPE_UNKNOWN	169
SKYPE_SUBTYPE_SKYPEOUT	55
SSL_SUBTYPE_UNKOWN	7
NTP	2

G) NDPI

Class	No. of Flows
skype	528
unknown	391
http	279
ssl_no_cert	4
steam	3

H) Libprotoident

Class	No. of Flows
Steam_Friends	505
Steam_UDP	405
HTTP	279
HTTPS	10
Steam_TCP	4
Unknown_TCP	2

I) NBAR

Class	No. of Flows
unclassified	910
http	279
secure-http	9
rtp	6
h323	1

A.2.24 TOR

A) PACE

Class	No. of Flows
TOR:no_subprotocols:not_detected	159
SSL:generic:not_detected	20
DNS:no_subprotocols:not_detected	6

B) OpenDPI

Class	No. of Flows
SSL	179
DNS	6

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	5
DNS	1

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	5
DNS	1

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	5
DNS	1

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	5
DNS	1

G) NDPI

Class	No. of Flows
skype	160
ssl_no_cert	13
Tor	6
dns	6

H) Libprotoident

Class	No. of Flows
HTTPS	91
TOR	62
SSL/TLS	26
Unknown_UDP	4
DNS	2

I) NBAR

Class	No. of Flows
secure-http	87
unclassified	84
dns	6
http	4
pptp	2
h323	1
pop3	1

A.2.25 World of Warcraft

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	16
World of Warcraft:no_subprotocols:not_detected	6

B) OpenDPI

Class	No. of Flows
HTTP	19
UNKNOWN	3

C) L7-filter-all

Class	No. of Flows
FINGER	14
SKYPE_SUBTYPE_SKYPEOUT	5
UNKNOWN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	14
HTTP_SUBTYPE_UNKNOWN	8

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	14
HTTP_SUBTYPE_UNKNOWN	8

F) L7-filter-com

Class	No. of Flows
UNKNOWN	12
HTTP_SUBTYPE_UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	5

G) NDPI

Class	No. of Flows
http	18
worldofwarcraft	3
google	1

H) Libprotoident

Class	No. of Flows
HTTP	19
WorldOfWarcraft	3

I) NBAR

Class	No. of Flows
http	19
unclassified	3

A.3 Web Services

A.3.1 4Shared

A) PACE

Class	No. of Flows
DirectDownloadLink:4shared.com:not_detected	83
unknown:no_subprotocols:not_yet_detected	11
SSL:generic:not_detected	4

B) OpenDPI

Class	No. of Flows
DIRECT_DOWNLOAD_LINK	82
UNKNOWN	11
SSL	4
HTTP	1

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	64
FINGER	19
UNKNOWN	7
HTTP_SUBTYPE_UNKNOWN	4
SSL_SUBTYPE_UNKOWN	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	81
HTTP_SUBTYPE_UNKNOWN	13
SSL_SUBTYPE_UNKOWN	4

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	81
HTTP_SUBTYPE_UNKNOWN	13
SSL_SUBTYPE_UNKOWN	4

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	64
UNKNOWN	24
HTTP_SUBTYPE_UNKNOWN	6
SSL_SUBTYPE_UNKOWN	4

G) NDPI

Class	No. of Flows
http	86
unknown	7
skype	4
http_connect	1

H) Libprotoident

Class	No. of Flows
HTTP	87
No_Payload	7
HTTPS	4

I) NBAR

Class	No. of Flows
http	87
unclassified	7
secure-http	4

A.3.2 Amazon

A) PACE

Class	No. of Flows
HTTP:generic:amazon_cloud	152
HTTP:generic:not_detected	147
SSL:generic:amazon_cloud	146
unknown:no_subprotocols:not_yet_detected	89
HTTP:generic:amazon_shop	57
HTTP:generic:not_yet_detected	9
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	365
SSL	142
UNKNOWN	95

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	236
FINGER	178
UNKNOWN	90
SSL_SUBTYPE_UNKOWN	87
XUNLEI	8
HTTP_SUBTYPE_UNKNOWN	2
SSL_SUBTYPE_VALIDCERTSSL	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	338
SSL_SUBTYPE_UNKOWN	146
HTTP_SUBTYPE_UNKNOWN	89
HTTP_SUBTYPE_CACHEHIT	19
XUNLEI	8
HTTP_SUBTYPE_CHACHEMISS	1
SSL_SUBTYPE_VALIDCERTSSL	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	343
SSL_SUBTYPE_UNKOWN	146
HTTP_SUBTYPE_UNKNOWN	92
HTTP_SUBTYPE_CACHEHIT	19
HTTP_SUBTYPE_CHACHEMISS	1
SSL_SUBTYPE_VALIDCERTSSL	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	236
UNKNOWN	208
SSL_SUBTYPE_UNKOWN	87
HTTP_SUBTYPE_UNKNOWN	62
XUNLEI	8
SSL_SUBTYPE_VALIDCERTSSL	1

G) NDPI

Class	No. of Flows
http	365
ssl_no_cert	136
unknown	90
ssl	11

H) Libprotoident

Class	No. of Flows
HTTP	360
HTTPS	148
No_Payload	89
BitTorrent	5

I) NBAR

Class	No. of Flows
http	365
secure-http	148
unclassified	89

A.3.3 Apple

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	353
unknown:no_subprotocols:not_yet_detected	94
SSL:generic:facebook	19
HTTP:generic:not_yet_detected	4
QUICKTIME:no_subprotocols:itunes	2
SSL:generic:not_detected	2
HTTP:generic:itunes	2
QUICKTIME:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	359
UNKNOWN	96
SSL	19
QUICKTIME	3

C) L7-filter-all

Class	No. of Flows
FINGER	332
UNKNOWN	79
SKYPE_SUBTYPE_SKYPEOUT	28
SSL_SUBTYPE_UNKOWN	21
HTTP_SUBTYPE_UNKNOWN	15
ITUNES	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	403
HTTP_SUBTYPE_UNKNOWN	51
SSL_SUBTYPE_UNKOWN	21
ITUNES	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	403
HTTP_SUBTYPE_UNKNOWN	51
SSL_SUBTYPE_UNKOWN	21
ITUNES	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	378
HTTP_SUBTYPE_UNKNOWN	48
SKYPE_SUBTYPE_SKYPEOUT	28
SSL_SUBTYPE_UNKOWN	21
ITUNES	2

G) NDPI

Class	No. of Flows
http	372
unknown	79
ssl	19
Apple	6
skype	1

H) Libprotoident

Class	No. of Flows
HTTP	377
No_Payload	79
HTTPS	21

I) NBAR

Class	No. of Flows
http	377
unclassified	79
secure-http	21

A.3.4 Ask

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	169
unknown:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	169
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	96
FINGER	73
UNKNOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	170
HTTP_SUBTYPE_UNKNOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	170
HTTP_SUBTYPE_UNKNOWN	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	96
UNKNOWN	74
HTTP_SUBTYPE_UNKNOWN	1

G) NDPI

Class	No. of Flows
http	169
unknown	2

H) Libprotoident

Class	No. of Flows
HTTP	169
No_Payload	2

I) NBAR

Class	No. of Flows
http	169
unclassified	2

A.3.5 Bing

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	412
unknown:no_subprotocols:not_yet_detected	25
HTTP:generic:not_yet_detected	14
MPEG:no_subprotocols:not_detected	2
SSL:generic:not_detected	2
FLASH:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	426
UNKNOWN	25
FLASH	3
SSL	2

C) L7-filter-all

Class	No. of Flows
FINGER	425
UNKNOWN	23
SKYPE_SUBTYPE_SKYPEOUT	4
HTTP_SUBTYPE_UNKNOWN	2
SSL_SUBTYPE_UNKOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	288
HTTP_SUBTYPE_UNKNOWN	166
SSL_SUBTYPE_UNKOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	288
HTTP_SUBTYPE_UNKNOWN	166
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	286
HTTP_SUBTYPE_UNKNOWN	164
SKYPE_SUBTYPE_SKYPEOUT	4
SSL_SUBTYPE_UNKOWN	2

G) NDPI

Class	No. of Flows
http	431
unknown	23
ssl_no_cert	2

H) Libprotoident

Class	No. of Flows
HTTP	431
No_Payload	23
HTTPS	2

I) NBAR

Class	No. of Flows
http	431
unclassified	23
secure-http	2

A.3.6 Blogspot

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	204
unknown:no_subprotocols:not_yet_detected	18
Google:encrypted:not_detected	9
HTTP:generic:not_yet_detected	2
SPDY:ssl:not_detected	1
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	206
UNKNOWN	26
SSL	3

C) L7-filter-all

Class	No. of Flows
FINGER	199
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	11
SKYPE_SUBTYPE_SKYPEOUT	7

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	193
UNKNOWN	30
SSL_SUBTYPE_UNKOWN	11
SOCKS	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	193
UNKNOWN	30
SSL_SUBTYPE_UNKOWN	11
SOCKS	1

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	187
UNKNOWN	30
SSL_SUBTYPE_UNKOWN	11
SKYPE_SUBTYPE_SKYPEOUT	7

G) NDPI

Class	No. of Flows
google	219
http	11
skype	4
unknown	1

H) Libprotoident

Class	No. of Flows
HTTP	206
No_Payload	18
HTTPS	11

I) NBAR

Class	No. of Flows
http	205
unclassified	19
secure-http	11

A.3.7 CNN

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	186
HTTP:generic:not_yet_detected	36
unknown:no_subprotocols:not_yet_detected	24
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	222
UNKNOWN	24
SSL	1

C) L7-filter-all

Class	No. of Flows
FINGER	216
UNKNOWN	24
SKYPE_SUBTYPE_SKYPEOUT	5
SSL_SUBTYPE_UNKOWN	1
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	184
HTTP_SUBTYPE_UNKNOWN	61
SSL_SUBTYPE_UNKOWN	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	185
HTTP_SUBTYPE_UNKNOWN	61
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	181
HTTP_SUBTYPE_UNKNOWN	59
SKYPE_SUBTYPE_SKYPEOUT	5
SSL_SUBTYPE_UNKOWN	1
XUNLEI	1

G) NDPI

Class	No. of Flows
http	197
skype	26
unknown	24

H) Libprotoident

Class	No. of Flows
HTTP	222
No_Payload	24
HTTPS	1

I) NBAR

Class	No. of Flows
http	222
unclassified	24
secure-http	1

A.3.8 Craigslist

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	162
unknown:no_subprotocols:not_yet_detected	15
HTTP:generic:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	164
UNKNOWN	15

C) L7-filter-all

Class	No. of Flows
FINGER	161
UNKNOWN	15
SKYPE_SUBTYPE_SKYPEOUT	3

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	163
UNKNOWN	16

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	163
UNKNOWN	16

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	160
UNKNOWN	16
SKYPE_SUBTYPE_SKYPEOUT	3

G) NDPI

Class	No. of Flows
http	164
unknown	15

H) Libprotoident

Class	No. of Flows
HTTP	164
No_Payload	15

I) NBAR

Class	No. of Flows
http	164
unclassified	15

A.3.9 Cyworld

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	234
unknown:no_subprotocols:not_yet_detected	79
HTTP:generic:not_yet_detected	13
FLASH:no_subprotocols:not_detected	5
unknown:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	247
UNKNOWN	80
FLASH	5

C) L7-filter-all

Class	No. of Flows
FINGER	171
SKYPE_SUBTYPE_SKYPEOUT	90
UNKNOWN	67
KUGOO	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	249
HTTP_SUBTYPE_UNKNOWN	79
KUGOO	4

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	253
HTTP_SUBTYPE_UNKNOWN	79

F) L7-filter-com

Class	No. of Flows
UNKNOWN	194
SKYPE_SUBTYPE_SKYPEOUT	90
HTTP_SUBTYPE_UNKNOWN	44
KUGOO	4

G) NDPI

Class	No. of Flows
http	249
unknown	57
skype	23
flash	3

H) Libprotoident

Class	No. of Flows
HTTP	272
No_Payload	57
RTMP	3

I) NBAR

Class	No. of Flows
http	272
unclassified	60

A.3.10 Doubleclick

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	1455
unknown:no_subprotocols:not_yet_detected	273
HTTP:generic:not_yet_detected	137
MEEBO:unknown:not_detected	52
WINDOWSMEDIA:no_subprotocols:windowsmedia	23
SPDY:ssl:not_detected	21
SSL:generic:not_detected	19
HTTP:generic:windowsmedia	5
WINDOWSMEDIA:no_subprotocols:not_detected	4

B) OpenDPI

Class	No. of Flows
HTTP	1649
UNKNOWN	285
SSL	28
WINDOWSMEDIA	27

C) L7-filter-all

Class	No. of Flows
FINGER	1485
UNKNOWN	272
SKYPE_SUBTYPE_SKYPEOUT	191
SSL_SUBTYPE_VALIDCERTSSL	21
SSL_SUBTYPE_UNKOWN	15
SKYPE_SUBTYPE_AUDIO	4
HTTP_SUBTYPE_UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1535
UNKNOWN	386
HTTP_SUBTYPE_VIDEO	28
SSL_SUBTYPE_VALIDCERTSSL	21
SSL_SUBTYPE_UNKOWN	19

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1535
UNKNOWN	386
HTTP_SUBTYPE_VIDEO	28
SSL_SUBTYPE_VALIDCERTSSL	21
SSL_SUBTYPE_UNKOWN	19

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1358
UNKNOWN	372
SKYPE_SUBTYPE_SKYPEOUT	191
HTTP_SUBTYPE_VIDEO	28
SSL_SUBTYPE_VALIDCERTSSL	21
SSL_SUBTYPE_UNKOWN	15
SKYPE_SUBTYPE_AUDIO	4

G) NDPI

Class	No. of Flows
google	1892
http	66
unknown	23
skype	6
ssl_no_cert	2

H) Libprotoident

Class	No. of Flows
HTTP	1676
No_Payload	272
HTTPS	40
BitTorrent	1

I) NBAR

Class	No. of Flows
http	1676
unclassified	273
secure-http	40

A.3.11 eBay

A) PACE

Class	No. of Flows
HTTP:generic:ebay	189
unknown:no_subprotocols:not_yet_detected	77
HTTP:generic:not_detected	8
SSL:generic:not_yet_detected	3
SSL:generic:ebay	2
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	197
UNKNOWN	77
SSL	7

C) L7-filter-all

Class	No. of Flows
FINGER	193
UNKNOWN	77
SSL_SUBTYPE_UNKOWN	7
SKYPE_SUBTYPE_SKYPEOUT	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	141
HTTP_SUBTYPE_UNKNOWN	133
SSL_SUBTYPE_UNKOWN	7

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	141
HTTP_SUBTYPE_UNKNOWN	133
SSL_SUBTYPE_UNKOWN	7

F) L7-filter-com

Class	No. of Flows
UNKNOWN	141
HTTP_SUBTYPE_UNKNOWN	129
SSL_SUBTYPE_UNKOWN	7
SKYPE_SUBTYPE_SKYPEOUT	4

G) NDPI

Class	No. of Flows
http	197
unknown	77
ssl	5
ssl_no_cert	2

H) Libprotoident

Class	No. of Flows
HTTP	197
No_Payload	77
HTTPS	7

I) NBAR

Class	No. of Flows
http	197
unclassified	77
secure-http	7

A.3.12 Facebook

A) PACE

Class	No. of Flows
HTTP:generic:facebook	5420
unknown:no_subprotocols:not_yet_detected	1209
SSL:generic:facebook	109
SPDY:ssl:facebook	73
HTTP:generic:not_yet_detected	59
HTTP:generic:not_detected	58
MPEG:no_subprotocols:facebook	10
SSL:generic:not_detected	8
FLASH:no_subprotocols:facebook	4
SSL:generic:not_yet_detected	2
OGG:no_subprotocols:facebook	1

B) OpenDPI

Class	No. of Flows
HTTP	5539
UNKNOWN	1243
SSL	156
QUICKTIME	8
FLASH	4
MPEG	2
OGG	1

C) L7-filter-all

Class	No. of Flows
FINGER	4897
UNKNOWN	1125
SKYPE_SUBTYPE_SKYPEOUT	417
HTTP_SUBTYPE_UNKNOWN	324
SSL_SUBTYPE_UNKOWN	149
SKYPE_SUBTYPE_AUDIO	39
SSL_SUBTYPE_VALIDCERTSSL	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	6122
HTTP_SUBTYPE_UNKNOWN	640
SSL_SUBTYPE_UNKOWN	188
SSL_SUBTYPE_VALIDCERTSSL	2
PPLIVE	1

E) L7-filter-aut

Class	No. of Flows
FACEBOOK	5435
UNKNOWN	1228
SSL_SUBTYPE_UNKOWN	188
HTTP_SUBTYPE_UNKNOWN	100
SSL_SUBTYPE_VALIDCERTSSL	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	5730
HTTP_SUBTYPE_UNKNOWN	615
SKYPE_SUBTYPE_SKYPEOUT	417
SSL_SUBTYPE_UNKOWN	149
SKYPE_SUBTYPE_AUDIO	39
SSL_SUBTYPE_VALIDCERTSSL	2
PPLIVE	1

G) NDPI

Class	No. of Flows
http	5634
unknown	1237
skype	29
ssl	24
ssl_no_cert	23
facebook	6

H) Libprotoident

Class	No. of Flows
HTTP	5637
No_Payload	1123
HTTPS	192
BitTorrent	1

I) NBAR

Class	No. of Flows
http	5622
unclassified	1139
secure-http	192

A.3.13 Go.com

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	229
unknown:no_subprotocols:not_yet_detected	70
HTTP:generic:not_yet_detected	24
SSL:generic:not_detected	8
FLASH:no_subprotocols:not_detected	3
QUICKTIME:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	253
UNKNOWN	78
FLASH	3
QUICKTIME	1

C) L7-filter-all

Class	No. of Flows
FINGER	219
UNKNOWN	43
SKYPE_SUBTYPE_SKYPEOUT	37
HTTP_SUBTYPE_UNKNOWN	27
SSL_SUBTYPE_UNKOWN	8
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	159
UNKNOWN	159
SSL_SUBTYPE_UNKOWN	8
HTTP_SUBTYPE_CACHEHIT	7
HTTP_SUBTYPE_CHACHEMISS	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	160
UNKNOWN	159
SSL_SUBTYPE_UNKOWN	8
HTTP_SUBTYPE_CACHEHIT	7
HTTP_SUBTYPE_CHACHEMISS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	141
HTTP_SUBTYPE_UNKNOWN	140
SKYPE_SUBTYPE_SKYPEOUT	37
SSL_SUBTYPE_UNKOWN	8
HTTP_SUBTYPE_CACHEHIT	7
HTTP_SUBTYPE_CHACHEMISS	1
XUNLEI	1

G) NDPI

Class	No. of Flows
http	284
unknown	43
skype	8

H) Libprotoident

Class	No. of Flows
HTTP	284
No_Payload	43
HTTPS	8

I) NBAR

Class	No. of Flows
http	281
unclassified	43
secure-http	8
h323	3

A.3.14 Google

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	3338
unknown:no_subprotocols:not_yet_detected	900
HTTP:media:not_detected	699
Google:encrypted:not_detected	673
SSL:generic:not_detected	453
HTTP:generic:not_yet_detected	248
SPDY:ssl:not_detected	134
FLASH:no_subprotocols:not_detected	60
Google:plus:not_detected	8
HTTP:generic:gmail	7
SSL:generic:gmail	6
Google:encrypted:not_yet_detected	5
SSL:generic:not_yet_detected	3
Google:drive:not_detected	2
Google:plus:not_yet_detected	2
SPDY:ssl:gmail	2
Google:docs:googledocs	1

B) OpenDPI

Class	No. of Flows
HTTP	4293
UNKNOWN	1184
SSL	1003
FLASH	61

C) L7-filter-all

Class	No. of Flows
FINGER	2794
SKYPE_SUBTYPE_SKYPEOUT	1094
SSL_SUBTYPE_UNKOWN	1000
UNKNOWN	899
HTTP_SUBTYPE_UNKNOWN	462
SSL_SUBTYPE_VALIDCERTSSL	232
SKYPE_SUBTYPE_AUDIO	54
ARMAGETRON	3
DNS	2
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	3660
UNKNOWN	1588
SSL_SUBTYPE_UNKOWN	1053
SSL_SUBTYPE_VALIDCERTSSL	232
ARMAGETRON	4
DNS	2
HTTP_SUBTYPE_VIDEO	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	3661
UNKNOWN	1588
SSL_SUBTYPE_UNKOWN	1053
SSL_SUBTYPE_VALIDCERTSSL	232
ARMAGETRON	4
DNS	2
HTTP_SUBTYPE_VIDEO	1

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	2747
UNKNOWN	1406
SKYPE_SUBTYPE_SKYPEOUT	1094
SSL_SUBTYPE_UNKOWN	1000
SSL_SUBTYPE_VALIDCERTSSL	232
SKYPE_SUBTYPE_AUDIO	54
ARMAGETRON	4
DNS	2
HTTP_SUBTYPE_VIDEO	1
XUNLEI	1

G) NDPI

Class	No. of Flows
google	4847
http	1223
unknown	246
skype	165
ssl_no_cert	55
ssl	5

H) Libprotoident

Class	No. of Flows
HTTP	4352
HTTPS	1292
No_Payload	892
BitTorrent	5

I) NBAR

Class	No. of Flows
http	4350
secure-http	1293
unclassified	898

A.3.15 Instagram

A) PACE

Class	No. of Flows
HTTP:generic:instagram	8
unknown:no_subprotocols:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	8
UNKNOWN	1

C) L7-filter-all

Class	No. of Flows
FINGER	7
SKYPE_SUBTYPE_SKYPEOUT	1
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	8
HTTP_SUBTYPE_UNKNOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	8
HTTP_SUBTYPE_UNKNOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	7
SKYPE_SUBTYPE_SKYPEOUT	1
HTTP_SUBTYPE_UNKNOWN	1

G) NDPI

Class	No. of Flows
http	8
unknown	1

H) Libprotoident

Class	No. of Flows
HTTP	8
No_Payload	1

I) NBAR

Class	No. of Flows
http	8
unclassified	1

A.3.16 Justin.tv

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	1768
unknown:no_subprotocols:not_yet_detected	294
FLASH:no_subprotocols:not_detected	167
HTTP:generic:not_yet_detected	97

B) OpenDPI

Class	No. of Flows
HTTP	1865
UNKNOWN	294
FLASH	167

C) L7-filter-all

Class	No. of Flows
FINGER	1445
XUNLEI	474
UNKNOWN	278
SKYPE_SUBTYPE_SKYPEOUT	110
HTTP_SUBTYPE_UNKNOWN	19

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1251
HTTP_SUBTYPE_UNKNOWN	601
XUNLEI	474

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1486
HTTP_SUBTYPE_UNKNOWN	840

F) L7-filter-com

Class	No. of Flows
UNKNOWN	1197
HTTP_SUBTYPE_UNKNOWN	544
XUNLEI	474
SKYPE_SUBTYPE_SKYPEOUT	110
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
http	2049
unknown	277

H) Libprotoident

Class	No. of Flows
HTTP	1963
No_Payload	278
HTTP_NonStandard	77
BitTorrent	7
HTTP_443	1

I) NBAR

Class	No. of Flows
http	1976
unclassified	283
secure-http	67

A.3.17 LinkedIn

A) PACE

Class	No. of Flows
HTTP:generic:linkedin	30
SSL:generic:linkedin	18
unknown:no_subprotocols:not_yet_detected	9
unknown:no_subprotocols:not_detected	5

B) OpenDPI

Class	No. of Flows
HTTP	29
SSL	18
UNKNOWN	15

C) L7-filter-all

Class	No. of Flows
FINGER	28
SSL_SUBTYPE_UNKOWN	18
UNKNOWN	9
HTTP_SUBTYPE_UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	29
SSL_SUBTYPE_UNKOWN	18
HTTP_SUBTYPE_UNKNOWN	15

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	29
SSL_SUBTYPE_UNKOWN	18
HTTP_SUBTYPE_UNKNOWN	15

F) L7-filter-com

Class	No. of Flows
UNKNOWN	27
SSL_SUBTYPE_UNKOWN	18
HTTP_SUBTYPE_UNKNOWN	15
SKYPE_SUBTYPE_SKYPEOUT	2

G) NDPI

Class	No. of Flows
http	32
skype	21
unknown	9

H) Libprotoident

Class	No. of Flows
HTTP	35
HTTPS	18
No_Payload	9

I) NBAR

Class	No. of Flows
http	35
secure-http	18
unclassified	9

A.3.18 Mediafire

A) PACE

Class	No. of Flows
SSL:generic:not_detected	326
DirectDownloadLink:mediafire.com:not_detected	143
unknown:no_subprotocols:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
UNKNOWN	329
DIRECT_DOWNLOAD_LINK	143

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	326
FINGER	121
SKYPE_SUBTYPE_SKYPEOUT	20
HTTP_SUBTYPE_UNKNOWN	2
UNKNOWN	2
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	326
UNKNOWN	143
HTTP_SUBTYPE_UNKNOWN	2
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	326
UNKNOWN	144
HTTP_SUBTYPE_UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	326
UNKNOWN	123
SKYPE_SUBTYPE_SKYPEOUT	20
HTTP_SUBTYPE_UNKNOWN	2
XUNLEI	1

G) NDPI

Class	No. of Flows
skype	326
http	144
unknown	2

H) Libprotoident

Class	No. of Flows
HTTPS	326
HTTP	144
No_Payload	2

I) NBAR

Class	No. of Flows
secure-http	326
http	144
unclassified	2

A.3.19 MSN

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	652
unknown:no_subprotocols:not_yet_detected	226
HTTP:generic:not_yet_detected	42
QUICKTIME:no_subprotocols:not_detected	3
SSL:generic:not_detected	3
FLASH:no_subprotocols:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	694
UNKNOWN	226
QUICKTIME	3
SSL	3
FLASH	2

C) L7-filter-all

Class	No. of Flows
FINGER	593
UNKNOWN	222
SKYPE_SUBTYPE_SKYPEOUT	106
HTTP_SUBTYPE_UNKNOWN	4
SOCKS	2
SSL_SUBTYPE_UNKOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	721
HTTP_SUBTYPE_UNKNOWN	199
HTTP_SUBTYPE_VIDEO	4
SOCKS	2
NBNS	1
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	721
HTTP_SUBTYPE_UNKNOWN	199
HTTP_SUBTYPE_VIDEO	4
SOCKS	2
NBNS	1
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	656
HTTP_SUBTYPE_UNKNOWN	158
SKYPE_SUBTYPE_SKYPEOUT	106
HTTP_SUBTYPE_VIDEO	4
SOCKS	2
NBNS	1
SSL_SUBTYPE_UNKOWN	1

G) NDPI

Class	No. of Flows
http	671
unknown	212
skype	42
ssl_no_cert	3

H) Libprotoident

Class	No. of Flows
HTTP	701
No_Payload	222
HTTPS	3
BitTorrent	2

I) NBAR

Class	No. of Flows
http	703
unclassified	222
secure-http	3

A.3.20 MySpace

A) PACE

Class	No. of Flows
HTTP:generic:myspace	2

B) OpenDPI

Class	No. of Flows
HTTP	2

C) L7-filter-all

Class	No. of Flows
FINGER	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	2

G) NDPI

Class	No. of Flows
http	2

H) Libprotoident

Class	No. of Flows
HTTP	2

I) NBAR

Class	No. of Flows
http	2

A.3.21 Pinterest

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	134
HTTP:generic:not_yet_detected	23
unknown:no_subprotocols:not_yet_detected	23
SSL:generic:not_detected	7
unknown:no_subprotocols:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	157
UNKNOWN	30
SSL	2

C) L7-filter-all

Class	No. of Flows
FINGER	116
SKYPE_SUBTYPE_SKYPEOUT	35
UNKNOWN	23
SSL_SUBTYPE_UNKOWN	7
XUNLEI	5
HTTP_SUBTYPE_UNKNOWN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	119
HTTP_SUBTYPE_CACHEHIT	29
HTTP_SUBTYPE_UNKNOWN	25
SSL_SUBTYPE_UNKOWN	7
XUNLEI	5
HTTP_SUBTYPE_CHACHEMISS	4

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	121
HTTP_SUBTYPE_CACHEHIT	29
HTTP_SUBTYPE_UNKNOWN	28
SSL_SUBTYPE_UNKOWN	7
HTTP_SUBTYPE_CHACHEMISS	4

F) L7-filter-com

Class	No. of Flows
UNKNOWN	89
SKYPE_SUBTYPE_SKYPEOUT	35
HTTP_SUBTYPE_CACHEHIT	27
HTTP_SUBTYPE_UNKNOWN	22
SSL_SUBTYPE_UNKOWN	7
XUNLEI	5
HTTP_SUBTYPE_CHACHEMISS	4

G) NDPI

Class	No. of Flows
http	159
unknown	23
skype	7

H) Libprotoident

Class	No. of Flows
HTTP	159
No_Payload	23
HTTPS	7

I) NBAR

Class	No. of Flows
http	159
unclassified	23
secure-http	7

A.3.22 Putlocker

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	87
unknown:no_subprotocols:not_yet_detected	13
SSL:generic:not_detected	2
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	88
UNKNOWN	15

C) L7-filter-all

Class	No. of Flows
FINGER	41
SKYPE_SUBTYPE_SKYPEOUT	33
HTTP_SUBTYPE_UNKNOWN	13
UNKNOWN	12
SSL_SUBTYPE_UNKOWN	2
XUNLEI	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	84
HTTP_SUBTYPE_UNKNOWN	15
SSL_SUBTYPE_UNKOWN	2
XUNLEI	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	86
HTTP_SUBTYPE_UNKNOWN	15
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	51
SKYPE_SUBTYPE_SKYPEOUT	33
HTTP_SUBTYPE_UNKNOWN	15
SSL_SUBTYPE_UNKOWN	2
XUNLEI	2

G) NDPI

Class	No. of Flows
http	89
unknown	12
skype	2

H) Libprotoident

Class	No. of Flows
HTTP	89
No_Payload	12
HTTPS	2

I) NBAR

Class	No. of Flows
http	74
secure-http	16
unclassified	13

A.3.23 QQ.com

A) PACE

Class	No. of Flows
QQLive:no_subprotocols:not_detected	242
HTTP:generic:not_detected	187
HTTP:generic:not_yet_detected	185
unknown:no_subprotocols:not_yet_detected	135
FLASH:no_subprotocols:not_detected	4

B) OpenDPI

Class	No. of Flows
HTTP	611
UNKNOWN	136
FLASH	6

C) L7-filter-all

Class	No. of Flows
FINGER	411
HTTP_SUBTYPE_UNKNOWN	142
UNKNOWN	132
SKYPE_SUBTYPE_SKYPEOUT	67
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	388
UNKNOWN	357
HTTP_SUBTYPE_CACHEHIT	5
HTTP_SUBTYPE_CHACHEMISS	2
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	389
UNKNOWN	357
HTTP_SUBTYPE_CACHEHIT	5
HTTP_SUBTYPE_CHACHEMISS	2

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	341
UNKNOWN	334
SKYPE_SUBTYPE_SKYPEOUT	70
HTTP_SUBTYPE_CACHEHIT	5
HTTP_SUBTYPE_CHACHEMISS	2
XUNLEI	1

G) NDPI

Class	No. of Flows
http	616
unknown	116
skype	21

H) Libprotoident

Class	No. of Flows
HTTP	620
No_Payload	111
Unknown_TCP	21
BitTorrent	1

I) NBAR

Class	No. of Flows
http	642
unclassified	111

A.3.24 Taobao

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	295
unknown:no_subprotocols:not_yet_detected	71
HTTP:generic:not_yet_detected	19
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	314
UNKNOWN	73

C) L7-filter-all

Class	No. of Flows
FINGER	294
HTTP_SUBTYPE_UNKNOWN	42
UNKNOWN	29
SKYPE_SUBTYPE_SKYPEOUT	20
SSL_SUBTYPE_UNKOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	197
HTTP_SUBTYPE_UNKNOWN	188
SSL_SUBTYPE_UNKOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	197
HTTP_SUBTYPE_UNKNOWN	188
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	194
HTTP_SUBTYPE_UNKNOWN	171
SKYPE_SUBTYPE_SKYPEOUT	20
SSL_SUBTYPE_UNKOWN	2

G) NDPI

Class	No. of Flows
http	356
unknown	29
skype	2

H) Libprotoident

Class	No. of Flows
HTTP	355
No_Payload	29
HTTPS	2
BitTorrent	1

I) NBAR

Class	No. of Flows
http	356
unclassified	29
secure-http	2

A.3.25 The Huffington Post

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	66
unknown:no_subprotocols:not_yet_detected	4
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	67
UNKNOWN	4

C) L7-filter-all

Class	No. of Flows
FINGER	47
SKYPE_SUBTYPE_SKYPEOUT	18
UNKNOWN	4
XUNLEI	2

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	50
UNKNOWN	19
XUNLEI	2

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	52
UNKNOWN	19

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	39
SKYPE_SUBTYPE_SKYPEOUT	18
UNKNOWN	12
XUNLEI	2

G) NDPI

Class	No. of Flows
http	67
unknown	4

H) Libprotoident

Class	No. of Flows
HTTP	67
No_Payload	4

I) NBAR

Class	No. of Flows
http	67
unclassified	4

A.3.26 Tumblr

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	299
unknown:no_subprotocols:not_yet_detected	66
HTTP:generic:not_yet_detected	17
unknown:no_subprotocols:not_detected	10
SSL:generic:not_detected	7
SSL:generic:not_yet_detected	3
SPDY:ssl:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	316
UNKNOWN	76
SSL	11

C) L7-filter-all

Class	No. of Flows
FINGER	272
HTTP_SUBTYPE_UNKNOWN	49
UNKNOWN	36
SKYPE_SUBTYPE_SKYPEOUT	20
HTTP_SUBTYPE_CACHEHIT	11
SSL_SUBTYPE_UNKOWN	10
XUNLEI	4
SSL_SUBTYPE_VALIDCERTSSL	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	188
UNKNOWN	122
HTTP_SUBTYPE_CACHEHIT	74
SSL_SUBTYPE_UNKOWN	10
XUNLEI	4
HTTP_SUBTYPE_CHACHEMISS	3
KUGOO	1
SSL_SUBTYPE_VALIDCERTSSL	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	192
UNKNOWN	123
HTTP_SUBTYPE_CACHEHIT	74
SSL_SUBTYPE_UNKOWN	10
HTTP_SUBTYPE_CHACHEMISS	3
SSL_SUBTYPE_VALIDCERTSSL	1

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	183
UNKNOWN	121
HTTP_SUBTYPE_CACHEHIT	60
SKYPE_SUBTYPE_SKYPEOUT	20
SSL_SUBTYPE_UNKOWN	10
XUNLEI	4
HTTP_SUBTYPE_CHACHEMISS	3
KUGOO	1
SSL_SUBTYPE_VALIDCERTSSL	1

G) NDPI

Class	No. of Flows
http	356
unknown	36
ssl	10
ssl_no_cert	1

H) Libprotoident

Class	No. of Flows
HTTP	356
No_Payload	36
HTTPS	11

I) NBAR

Class	No. of Flows
http	354
unclassified	38
secure-http	11

A.3.27 Twitter

A) PACE

Class	No. of Flows
HTTP:generic:twitter	555
unknown:no_subprotocols:not_yet_detected	325
SSL:generic:twitter	255
HTTP:generic:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
HTTP	558
UNKNOWN	452
SSL	128

C) L7-filter-all

Class	No. of Flows
UNKNOWN	307
FINGER	252
SKYPE_SUBTYPE_SKYPEOUT	177
SSL_SUBTYPE_UNKOWN	160
XUNLEI	128
SSL_SUBTYPE_VALIDCERTSSL	55
SKYPE_SUBTYPE_AUDIO	40
HTTP_SUBTYPE_UNKNOWN	19

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	379
HTTP_SUBTYPE_UNKNOWN	369
SSL_SUBTYPE_UNKOWN	200
XUNLEI	128
SSL_SUBTYPE_VALIDCERTSSL	55
HTTP_SUBTYPE_CACHEHIT	7

E) L7-filter-aut

Class	No. of Flows
TWITTER	554
UNKNOWN	310
SSL_SUBTYPE_UNKOWN	200
SSL_SUBTYPE_VALIDCERTSSL	55
HTTP_SUBTYPE_UNKNOWN	19

F) L7-filter-com

Class	No. of Flows
UNKNOWN	379
HTTP_SUBTYPE_UNKNOWN	192
SKYPE_SUBTYPE_SKYPEOUT	177
SSL_SUBTYPE_UNKOWN	160
XUNLEI	128
SSL_SUBTYPE_VALIDCERTSSL	55
SKYPE_SUBTYPE_AUDIO	40
HTTP_SUBTYPE_CACHEHIT	7

G) NDPI

Class	No. of Flows
http	577
unknown	352
ssl_no_cert	189
skype	15
ssl	5

H) Libprotoident

Class	No. of Flows
HTTP	576
No_Payload	307
HTTPS	255

I) NBAR

Class	No. of Flows
http	576
unclassified	307
secure-http	255

A.3.28 Vimeo

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	49
SSL:generic:not_detected	35
unknown:no_subprotocols:not_yet_detected	21
QUICKTIME:no_subprotocols:not_detected	11
FLASH:no_subprotocols:not_detected	9
SSL:generic:not_yet_detected	5
MPEG:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	61
HTTP	49
QUICKTIME	12
FLASH	9

C) L7-filter-all

Class	No. of Flows
FINGER	61
SSL_SUBTYPE_UNKOWN	40
UNKNOWN	20
HTTP_SUBTYPE_UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	5

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	72
SSL_SUBTYPE_UNKOWN	40
HTTP_SUBTYPE_UNKNOWN	18
HTTP_SUBTYPE_VIDEO	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	72
SSL_SUBTYPE_UNKOWN	40
HTTP_SUBTYPE_UNKNOWN	18
HTTP_SUBTYPE_VIDEO	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	68
SSL_SUBTYPE_UNKOWN	40
HTTP_SUBTYPE_UNKNOWN	17
SKYPE_SUBTYPE_SKYPEOUT	5
HTTP_SUBTYPE_VIDEO	1

G) NDPI

Class	No. of Flows
http	71
skype	35
unknown	20
ssl_no_cert	5

H) Libprotoident

Class	No. of Flows
HTTP	71
HTTPS	40
No_Payload	20

I) NBAR

Class	No. of Flows
http	71
secure-http	40
unclassified	20

A.3.29 VK.com

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	334
unknown:no_subprotocols:not_yet_detected	9

B) OpenDPI

Class	No. of Flows
HTTP	334
UNKNOWN	9

C) L7-filter-all

Class	No. of Flows
FINGER	322
SKYPE_SUBTYPE_SKYPEOUT	12
UNKNOWN	9

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	202
UNKNOWN	141

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	202
UNKNOWN	141

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	194
UNKNOWN	137
SKYPE_SUBTYPE_SKYPEOUT	12

G) NDPI

Class	No. of Flows
http	334
unknown	9

H) Libprotoident

Class	No. of Flows
HTTP	334
No_Payload	9

I) NBAR

Class	No. of Flows
http	334
unclassified	9

A.3.30 Wikipedia

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	3744
unknown:no_subprotocols:not_yet_detected	1873
HTTP:generic:not_yet_detected	440
SSL:generic:not_detected	22
SSL:generic:not_yet_detected	13

B) OpenDPI

Class	No. of Flows
HTTP	4189
UNKNOWN	1901
SSL	2

C) L7-filter-all

Class	No. of Flows
FINGER	4151
UNKNOWN	1872
SSL_SUBTYPE_UNKOWN	34
SKYPE_SUBTYPE_SKYPEOUT	33
HTTP_SUBTYPE_CACHEHIT	1
SOCKS	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_CACHEHIT	2248
UNKNOWN	1913
HTTP_SUBTYPE_UNKNOWN	1863
SSL_SUBTYPE_UNKOWN	34
HTTP_SUBTYPE_CHACHEMISS	33
SOCKS	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_CACHEHIT	2248
UNKNOWN	1913
HTTP_SUBTYPE_UNKNOWN	1863
SSL_SUBTYPE_UNKOWN	34
HTTP_SUBTYPE_CHACHEMISS	33
SOCKS	1

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_CACHEHIT	2247
UNKNOWN	1913
HTTP_SUBTYPE_UNKNOWN	1830
SKYPE_SUBTYPE_SKYPEOUT	34
SSL_SUBTYPE_UNKOWN	34
HTTP_SUBTYPE_CHACHEMISS	33
SOCKS	1

G) NDPI

Class	No. of Flows
http	4190
unknown	1867
ssl_no_cert	31
skype	4

H) Libprotoident

Class	No. of Flows
HTTP	4182
No_Payload	1856
HTTPS	35
Unknown_TCP	17
BitTorrent	2

I) NBAR

Class	No. of Flows
http	4201
unclassified	1856
secure-http	35

A.3.31 Windows Live

A) PACE

Class	No. of Flows
HTTP:generic:hotmail_webmail	12
SSL:generic:live_com	8
HTTP:generic:live_com	5
unknown:no_subprotocols:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	17
SSL	8
UNKNOWN	1

C) L7-filter-all

Class	No. of Flows
FINGER	17
SSL_SUBTYPE_UNKOWN	8
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	8

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	8

F) L7-filter-com

Class	No. of Flows
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	8

G) NDPI

Class	No. of Flows
http	17
ssl_no_cert	8
unknown	1

H) Libprotoident

Class	No. of Flows
HTTP	17
HTTPS	8
No_Payload	1

I) NBAR

Class	No. of Flows
http	17
secure-http	8
unclassified	1

A.3.32 Wordpress

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	142
unknown:no_subprotocols:not_yet_detected	19
SPDY:ssl:not_detected	7
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	143
UNKNOWN	26

C) L7-filter-all

Class	No. of Flows
FINGER	129
UNKNOWN	19
SKYPE_SUBTYPE_SKYPEOUT	14
SSL_SUBTYPE_UNKOWN	7

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	91
UNKNOWN	71
SSL_SUBTYPE_UNKOWN	7

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	91
UNKNOWN	71
SSL_SUBTYPE_UNKOWN	7

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	77
UNKNOWN	71
SKYPE_SUBTYPE_SKYPEOUT	14
SSL_SUBTYPE_UNKOWN	7

G) NDPI

Class	No. of Flows
http	143
unknown	19
ssl_no_cert	6
skype	1

H) Libprotoident

Class	No. of Flows
HTTP	143
No_Payload	19
HTTPS	7

I) NBAR

Class	No. of Flows
http	143
unclassified	19
secure-http	7

A.3.33 Yahoo

A) PACE

Class	No. of Flows
Yahoo:webmail:not_detected	9456
HTTP:generic:not_detected	4595
unknown:no_subprotocols:not_yet_detected	2742
HTTP:generic:not_yet_detected	286
FLASH:no_subprotocols:not_detected	147
SSL:generic:not_detected	62
Yahoo:unknown:not_detected	43
HTTP:generic:ebay	25
HTTP:generic:flickr	5
SSL:generic:not_yet_detected	5
Yahoo:webchat:not_detected	4
unknown:no_subprotocols:not_detected	2
FLASH:no_subprotocols:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	14456
UNKNOWN	2702
FLASH	148
SSL	67

C) L7-filter-all

Class	No. of Flows
FINGER	13965
UNKNOWN	2403
SKYPE_SUBTYPE_SKYPEOUT	750
HTTP_SUBTYPE_UNKNOWN	176
SSL_SUBTYPE_UNKOWN	60
XUNLEI	9
SKYPE_SUBTYPE_AUDIO	6
TSP	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	16095
HTTP_SUBTYPE_UNKNOWN	1203
SSL_SUBTYPE_UNKOWN	66
XUNLEI	9

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	16100
HTTP_SUBTYPE_UNKNOWN	1207
SSL_SUBTYPE_UNKOWN	66

F) L7-filter-com

Class	No. of Flows
UNKNOWN	15361
HTTP_SUBTYPE_UNKNOWN	1183
SKYPE_SUBTYPE_SKYPEOUT	750
SSL_SUBTYPE_UNKOWN	60
XUNLEI	9
SKYPE_SUBTYPE_AUDIO	6
TSP	4

G) NDPI

Class	No. of Flows
http	14519
unknown	2702
flash	82
ssl_no_cert	47
ssl	17
http_connect	5
yahoo	1

H) Libprotoident

Class	No. of Flows
HTTP	14482
No_Payload	2311
YahooError	410
RTMP	81
HTTPS	67
Unknown_TCP	21
Web_Junk	1

I) NBAR

Class	No. of Flows
http	14706
unclassified	2598
secure-http	67
irc	2

A.3.34 YouTube

A) PACE

Class	No. of Flows
HTTP:generic:youtube	1641
FLASH:no_subprotocols:youtube	361
unknown:no_subprotocols:not_yet_detected	348
SPDY:ssl:not_detected	42
Google:encrypted:not_detected	36
HTTP:generic:not_detected	24
HTTP:generic:not_yet_detected	22
SSL:generic:not_detected	17
Google:plus:not_detected	11
QUICKTIME:no_subprotocols:youtube	9
MPEG:no_subprotocols:youtube	8
HTTP:video:youtube	7
unknown:no_subprotocols:not_detected	4
Google:plus:not_yet_detected	2
Google:encrypted:not_yet_detected	1
WINDOWSMEDIA:no_subprotocols:youtube	1

B) OpenDPI

Class	No. of Flows
HTTP	1704
FLASH	362
UNKNOWN	357
SSL	102
QUICKTIME	9

C) L7-filter-all

Class	No. of Flows
FINGER	1881
UNKNOWN	347
SKYPE_SUBTYPE_SKYPEOUT	183
SSL_SUBTYPE_UNKOWN	97
SSL_SUBTYPE_VALIDCERTSSL	9
HTTP_SUBTYPE_UNKNOWN	7
XUNLEI	7
SKYPE_SUBTYPE_AUDIO	3

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1445
UNKNOWN	926
SSL_SUBTYPE_UNKOWN	100
HTTP_SUBTYPE_VIDEO	42
SSL_SUBTYPE_VALIDCERTSSL	9
XUNLEI	7
HTTP_SUBTYPE_AUDIO	4
KUGOO	1

E) L7-filter-aut

Class	No. of Flows
YOUTUBE	1551
UNKNOWN	791
SSL_SUBTYPE_UNKOWN	100
HTTP_SUBTYPE_UNKNOWN	66
HTTP_SUBTYPE_VIDEO	13
SSL_SUBTYPE_VALIDCERTSSL	9
HTTP_SUBTYPE_AUDIO	4

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1336
UNKNOWN	852
SKYPE_SUBTYPE_SKYPEOUT	183
SSL_SUBTYPE_UNKOWN	97
HTTP_SUBTYPE_VIDEO	42
SSL_SUBTYPE_VALIDCERTSSL	9
XUNLEI	7
HTTP_SUBTYPE_AUDIO	4
SKYPE_SUBTYPE_AUDIO	3
KUGOO	1

G) NDPI

Class	No. of Flows
google	1918
http	527
unknown	81
skype	6
ssl_no_cert	1
youtube	1

H) Libprotoident

Class	No. of Flows
HTTP	2077
No_Payload	342
HTTPS	109
BitTorrent	6

I) NBAR

Class	**No. of Flows**
http	2051
unclassified	374
secure-http	109

Appendix B

Dataset with Truncated Packets – Detailed Results

This section presents the detailed insight into the classification results performed on the dataset with truncated packets. The correct results are makred in green, wrong in red, while the unclassified items are left in black.

B.1 Application Protocols

B.1.1 DNS

A) PACE

Class	No. of Flows
DNS:no_subprotocols:not_detected	18242
unknown:no_subprotocols:not_detected	6
unknown:no_subprotocols:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
DNS	18249
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
UNKNOWN	15706
FINGER	848
SKYPE_SUBTYPE_SKYPEOUT	557
EDONKEY_SUBTYPE_PLAIN	362
NTP	323
DNS	281
KUGOO	135
TSP	27
SSL_SUBTYPE_UNKOWN	5
STUN	2
RTP	2
WORLDOFWARCRAFT	1
XUNLEI	1
QQ	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	17822
DNS	284
KUGOO	135
SSL_SUBTYPE_UNKOWN	5
STUN	2
QQ	1
WORLDOFWARCRAFT	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	17956
DNS	284
SSL_SUBTYPE_UNKOWN	5
QQ	2
STUN	2
WORLDOFWARCRAFT	1
XUNLEI	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	16552
SKYPE_SUBTYPE_SKYPEOUT	557
EDONKEY_SUBTYPE_PLAIN	362
NTP	323
DNS	283
KUGOO	135
TSP	27
SSL_SUBTYPE_UNKOWN	5
STUN	2
RTP	2
WORLDOFWARCRAFT	1
XUNLEI	1
QQ	1

G) NDPI

Class	No. of Flows
dns	18250
unknown	1

H) Libprotoident

Class	No. of Flows
DNS	18243
Unknown_UDP	7
Unknown_TCP	1

I) NBAR

Class	No. of Flows
dns	18250
unclassified	1

B.1.2 HTTP

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	39267
unknown:no_subprotocols:not_detected	3388
HTTP:generic:not_yet_detected	315
HTTP:generic:not_detected	13

B) OpenDPI

Class	No. of Flows
UNKNOWN	42800
HTTP	327

C) L7-filter-all

Class	No. of Flows
FINGER	39698
SKYPE_SUBTYPE_SKYPEOUT	2860
XUNLEI	499
SOULSEEK	53
UNKNOWN	10
KUGOO	4
EDONKEY_SUBTYPE_PLAIN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	41385
XUNLEI	1682
SOULSEEK	53
KUGOO	6
NBNS	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	43073
SOULSEEK	53
NBNS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	35755
SKYPE_SUBTYPE_SKYPEOUT	6656
XUNLEI	653
SOULSEEK	53
KUGOO	6
EDONKEY_SUBTYPE_PLAIN	3
NBNS	1

G) NDPI

Class	No. of Flows
unknown	21636
skype	14336
google	6523
green	601
H323	19
Apple	5
dropbox	4
Whois_Das	3

H) Libprotoident

Class	No. of Flows
HTTP	42737
HTTP_NonStandard	303
SOCKS5	53
BitTorrent	26
EMule	3
Web_Junk	3
HTTP_443	1
Unknown_TCP	1

I) NBAR

Class	No. of Flows
http	41950
unclassified	1102
secure-http	67
bittorrent	5
h323	3

B.1.3 ICMP

A) PACE

Class	No. of Flows
ICMP:no_subprotocols:not_detected	205

B) OpenDPI

Class	No. of Flows
ICMP	205

C) L7-filter-all

Class	No. of Flows
UNKNOWN	205

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	205

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	205

F) L7-filter-com

Class	No. of Flows
UNKNOWN	205

G) NDPI

Class	No. of Flows
icmp	205

H) Libprotoident

Class	No. of Flows
ICMP	205

I) NBAR

Class	No. of Flows
icmp	205

B.1.4 IMAP-STARTTLS

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	32
unknown:no_subprotocols:not_detected	3

B) OpenDPI

Class	No. of Flows
UNKNOWN	35

C) L7-filter-all

Class	No. of Flows
MAIL_IMAP	35

D) L7-filter-sel

Class	No. of Flows
MAIL_IMAP	35

E) L7-filter-aut

Class	No. of Flows
MAIL_IMAP	35

F) L7-filter-com

Class	No. of Flows
MAIL_IMAP	35

G) NDPI

Class	No. of Flows
unknown	35

H) Libprotoident

Class	No. of Flows
IMAP	35

I) NBAR

Class	No. of Flows
imap	35

B.1.5 IMAP-TLS

A) PACE

Class	No. of Flows
SSL:generic:not_detected	103

B) OpenDPI

Class	No. of Flows
SSL	103

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

G) NDPI

Class	No. of Flows
google	103

H) Libprotoident

Class	No. of Flows
IMAPS	103

I) NBAR

Class	No. of Flows
secure-imap	103

B.1.6 NETBIOS Name Service

A) PACE

Class	No. of Flows
NETBIOS:no_subprotocols:not_detected	6780
unknown:no_subprotocols:not_yet_detected	3413
unknown:no_subprotocols:not_detected	6

B) OpenDPI

Class	No. of Flows
NETBIOS	10047
UNKNOWN	152

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9265
SKYPE_SUBTYPE_SKYPEOUT	446
EDONKEY_SUBTYPE_PLAIN	258
NTP	118
RTP	111
FINGER	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	10199

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	10199

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9266
SKYPE_SUBTYPE_SKYPEOUT	446
EDONKEY_SUBTYPE_PLAIN	258
NTP	118
RTP	111

G) NDPI

Class	No. of Flows
netbios	10047
unknown	152

H) Libprotoident

Class	No. of Flows
Unknown_UDP	9691
RTP	502
NetBIOS_UDP	4
Kademlia	1
eMule_UDP	1

I) NBAR

Class	No. of Flows
netbios	10199

B.1.7 NETBIOS Session Service

A) PACE

Class	No. of Flows
NETBIOS:no_subprotocols:not_detected	11

B) OpenDPI

Class	No. of Flows
NETBIOS	11

C) L7-filter-all

Class	No. of Flows
UNKNOWN	11

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	11

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	11

F) L7-filter-com

Class	No. of Flows
UNKNOWN	11

G) NDPI

Class	No. of Flows
netbios	11

H) Libprotoident

Class	No. of Flows
NetBIOS	11

I) NBAR

Class	No. of Flows
netbios	11

B.1.8 SAMBA Session Service

A) PACE

Class	No. of Flows
SMB/CIFS:no_subprotocols:not_detected	42786
unknown:no_subprotocols:not_yet_detected	13
unknown:no_subprotocols:not_detected	9

B) OpenDPI

Class	No. of Flows
SMB	42786
UNKNOWN	22

C) L7-filter-all

Class	No. of Flows
SMB	42785
UNKNOWN	23

D) L7-filter-sel

Class	No. of Flows
SMB	42785
UNKNOWN	23

E) L7-filter-aut

Class	No. of Flows
SMB	42785
UNKNOWN	23

F) L7-filter-com

Class	No. of Flows
SMB	42785
UNKNOWN	23

G) NDPI

Class	No. of Flows
smb	42786
unknown	22

H) Libprotoident

Class	No. of Flows
SMB	42808

I) NBAR

Class	No. of Flows
unclassified	42806
pcanywhere	2

B.1.9 NTP

A) PACE

Class	No. of Flows
NTP:no_subprotocols:not_detected	42227

B) OpenDPI

Class	No. of Flows
NTP	42227

C) L7-filter-all

Class	No. of Flows
NTP	42165
EDONKEY_SUBTYPE_PLAIN	52
UNKNOWN	6
QQ	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	42195
QQ	32

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	42195
QQ	32

F) L7-filter-com

Class	No. of Flows
NTP	42165
EDONKEY_SUBTYPE_PLAIN	52
UNKNOWN	6
QQ	4

G) NDPI

Class	No. of Flows
ntp	42227

H) Libprotoident

Class	No. of Flows
NTP	42227

I) NBAR

Class	No. of Flows
ntp	42227

B.1.10 POP3-PLAIN

A) PACE

Class	No. of Flows
POP:no_subprotocols:not_detected	26

B) OpenDPI

Class	No. of Flows
MAIL_POP	26

C) L7-filter-all

Class	No. of Flows
MAIL_POP	26

D) L7-filter-sel

Class	No. of Flows
MAIL_POP	26

E) L7-filter-aut

Class	No. of Flows
MAIL_POP	26

F) L7-filter-com

Class	No. of Flows
MAIL_POP	26

G) NDPI

Class	No. of Flows
pop	26

H) Libprotoident

Class	No. of Flows
POP3	26

I) NBAR

Class	No. of Flows
pop3	26

B.1.11 POP3-TLS

A) PACE

Class	No. of Flows
SSL:generic:not_detected	99
unknown:no_subprotocols:not_detected	1
unknown:no_subprotocols:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
SSL	99
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	94
FINGER	5
SKYPE_SUBTYPE_SKYPEOUT	1
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	94
UNKNOWN	7

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	94
UNKNOWN	7

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	94
UNKNOWN	6
SKYPE_SUBTYPE_SKYPEOUT	1

G) NDPI

Class	No. of Flows
pops	87
google	12
ssl_no_cert	1
unknown	1

H) Libprotoident

Class	No. of Flows
POP3S	101

I) NBAR

Class	No. of Flows
secure-pop3	101

B.1.12 RTMP

A) PACE

Class	No. of Flows
FLASH:no_subprotocols:not_detected	329
unknown:no_subprotocols:not_yet_detected	43
FLASH:no_subprotocols:not_yet_detected	6

B) OpenDPI

Class	No. of Flows
FLASH	335
UNKNOWN	43

C) L7-filter-all

Class	No. of Flows
UNKNOWN	293
SKYPE_SUBTYPE_SKYPEOUT	45
TSP	37
QQ	2
H323	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	375
QQ	2
H323	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	375
QQ	2
H323	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	293
SKYPE_SUBTYPE_SKYPEOUT	45
TSP	37
QQ	2
H323	1

G) NDPI

Class	No. of Flows
flash	227
skype	94
unknown	42
H323	15

H) Libprotoident

Class	No. of Flows
RTMP	327
No_Payload	40
Unknown_TCP	8
SSL/TLS	2
BitTorrent	1

I) NBAR

Class	No. of Flows
unclassified	377
mgcp	1

B.1.13 SMTP-PLAIN

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	66
unknown:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	67

C) L7-filter-all

Class	No. of Flows
MAIL_SMTP	67

D) L7-filter-sel

Class	No. of Flows
MAIL_SMTP	67

E) L7-filter-aut

Class	No. of Flows
MAIL_SMTP	67

F) L7-filter-com

Class	No. of Flows
MAIL_SMTP	67

G) NDPI

Class	No. of Flows
unknown	67

H) Libprotoident

Class	No. of Flows
SMTP	67

I) NBAR

Class	No. of Flows
smtp	67

B.1.14 SMTP-TLS

A) PACE

Class	No. of Flows
SSL:generic:not_detected	50
unknown:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
SSL	50
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

G) NDPI

Class	No. of Flows
google	50
smtps	2

H) Libprotoident

Class	No. of Flows
SMTP_Secure	52

I) NBAR

Class	No. of Flows
unclassified	52

B.1.15 SOCKSv5

A) PACE

Class	No. of Flows
Socks:socksv5:not_yet_detected	1508
unknown:no_subprotocols:not_yet_detected	267
SSL:generic:not_detected	93
SSL:generic:not_yet_detected	48
unknown:no_subprotocols:not_detected	11

B) OpenDPI

Class	No. of Flows
UNKNOWN	1927

C) L7-filter-all

Class	No. of Flows
SOULSEEK	1927

D) L7-filter-sel

Class	No. of Flows
SOULSEEK	1927

E) L7-filter-aut

Class	No. of Flows
SOULSEEK	1927

F) L7-filter-com

Class	No. of Flows
SOULSEEK	1927

G) NDPI

Class	No. of Flows
skype	1927

H) Libprotoident

Class	No. of Flows
SOCKS5	1927

I) NBAR

Class	No. of Flows
unclassified	1927

B.1.16 SSH

A) PACE

Class	No. of Flows
SSH:no_subprotocols:not_detected	36615
unknown:no_subprotocols:not_yet_detected	2224
SSL:generic:not_detected	45
unknown:no_subprotocols:not_detected	45
SSL:generic:not_yet_detected	32

B) OpenDPI

Class	No. of Flows
SSH	36615
UNKNOWN	2269
SSL	77

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	33620
SSH	3078
UNKNOWN	1958
SSL_SUBTYPE_UNKOWN	164
FINGER	93
NTP	48

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	35719
SSH	3078
SSL_SUBTYPE_UNKOWN	164

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	35719
SSH	3078
SSL_SUBTYPE_UNKOWN	164

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	33620
SSH	3078
UNKNOWN	2051
SSL_SUBTYPE_UNKOWN	164
NTP	48

G) NDPI

Class	No. of Flows
ssh	36615
unknown	2257
ssl	77
skype	7
ssl_no_cert	3
H323	2

H) Libprotoident

Class	No. of Flows
SSH	36697
No_Payload	1851
HTTPS	272
HTTP	93
BitTorrent	47
Unknown_TCP	1

I) NBAR

Class	No. of Flows
ssh	36512
unclassified	1975
secure-http	272
h323	107
http	93
socks	1
xwindows	1

B.1.17 Webdav

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_detected	51
SSL:generic:not_detected	4
unknown:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	53
SSL	4

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	54
SKYPE_SUBTYPE_SKYPEOUT	2
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	54
UNKNOWN	3

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	54
UNKNOWN	3

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	54
SKYPE_SUBTYPE_SKYPEOUT	2
UNKNOWN	1

G) NDPI

Class	No. of Flows
skype	57

H) Libprotoident

Class	No. of Flows
HTTPS	55
HTTP	2

I) NBAR

Class	No. of Flows
secure-http	55
http	2

B.2 Applications

B.2.1 4Shared

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_detected	106
unknown:no_subprotocols:not_yet_detected	38

B) OpenDPI

Class	No. of Flows
UNKNOWN	144

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
FINGER	39

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
UNKNOWN	39

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
UNKNOWN	39

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
UNKNOWN	39

G) NDPI

Class	No. of Flows
skype	140
unknown	4

H) Libprotoident

Class	No. of Flows
HTTPS	105
HTTP	39

I) NBAR

Class	No. of Flows
secure-http	105
http	39

B.2.2 America's Army

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	320
unknown:no_subprotocols:not_detected	30

B) OpenDPI

Class	No. of Flows
UNKNOWN	350

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	316
UNKNOWN	19
FINGER	8
RTP	5
NTP	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	350

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	350

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	323
UNKNOWN	20
RTP	5
NTP	2

G) NDPI

Class	No. of Flows
unknown	199
skype	141
TeamSpeak	9
rtcp	1

H) Libprotoident

Class	No. of Flows
Steam_UDP	284
Unknown_UDP	38
HalfLife	28

I) NBAR

Class	No. of Flows
rtp	199
unclassified	150
rtcp	1

B.2.3 BitTorrent clients (encrypted)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	38527
BitTorrent:plain:not_detected	31898
BitTorrent:uTP:not_detected	25506
unknown:no_subprotocols:not_detected	344
eDonkey:encrypted:not_detected	84
BitTorrent:encrypted:not_detected	30
DNS:no_subprotocols:not_detected	10

B) OpenDPI

Class	No. of Flows
UNKNOWN	96389
DNS	10

C) L7-filter-all

Class	No. of Flows
UNKNOWN	47752
BITTORRENT_SUBTYPE_PLAIN	39034
SKYPE_SUBTYPE_SKYPEOUT	3569
FINGER	2978
NTP	1325
EDONKEY_SUBTYPE_PLAIN	771
KUGOO	408
QQ	217
SKYPE_SUBTYPE_AUDIO	158
STUN	156
RTP	15
TSP	10
SOULSEEK	3
SSL_SUBTYPE_UNKOWN	1
LPD	1
PPLIVE	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	56515
BITTORRENT_SUBTYPE_PLAIN	39058
KUGOO	425
QQ	231
STUN	164
SOULSEEK	3
LPD	1
PPLIVE	1
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	56941
BITTORRENT_SUBTYPE_PLAIN	39058
QQ	231
STUN	164
SOULSEEK	3
LPD	1
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	50556
BITTORRENT_SUBTYPE_PLAIN	39035
SKYPE_SUBTYPE_SKYPEOUT	3681
NTP	1356
EDONKEY_SUBTYPE_PLAIN	786
KUGOO	413
QQ	218
SKYPE_SUBTYPE_AUDIO	161
STUN	160
RTP	16
TSP	11
SOULSEEK	3
SSL_SUBTYPE_UNKOWN	1
LPD	1
PPLIVE	1

G) NDPI

Class	No. of Flows
bittorrent	50921
skype	22941
unknown	22527
dns	10

H) Libprotoident

Class	No. of Flows
BitTorrent_UDP	57987
Unknown_TCP	36876
Unknown_UDP	1289
HTTP_NonStandard	110
No_Payload	74
HTTP	16
BitTorrent	14
DNS	10
RTMP	7
Gnutella_UDP	6
Invalid_Bittorrent	6
Web_Junk	2
Xunlei	1
Mystery_8000	1

I) NBAR

Class	No. of Flows
unclassified	92975
skype	2679
h323	598
http	123
dns	10
pcanywhere	4
xwindows	3
bittorrent	3
sqlserver	1
nfs	1
novadigm	1
rsvp	1

B.2.4 BitTorrent clients (non-encrypted)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	172034
eDonkey:encrypted:not_detected	40732
BitTorrent:plain:not_detected	29182
BitTorrent:uTP:not_detected	19285
unknown:no_subprotocols:not_detected	279
DNS:no_subprotocols:not_detected	12
SSL:generic:not_detected	2
BitTorrent:encrypted:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	261513
DNS	12
SSL	2

C) L7-filter-all

Class	No. of Flows
NTP	210694
BITTORRENT_SUBTYPE_PLAIN	36645
UNKNOWN	12990
SKYPE_SUBTYPE_SKYPEOUT	778
FINGER	196
QQ	129
SKYPE_SUBTYPE_AUDIO	60
EDONKEY_SUBTYPE_PLAIN	16
KUGOO	10
STUN	6
SSL_SUBTYPE_UNKOWN	2
PPLIVE	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	224699
BITTORRENT_SUBTYPE_PLAIN	36664
QQ	135
KUGOO	17
STUN	6
NBNS	3
SSL_SUBTYPE_UNKOWN	2
PPLIVE	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	224717
BITTORRENT_SUBTYPE_PLAIN	36664
QQ	135
STUN	6
NBNS	3
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
NTP	210694
BITTORRENT_SUBTYPE_PLAIN	36645
UNKNOWN	13183
SKYPE_SUBTYPE_SKYPEOUT	780
QQ	130
SKYPE_SUBTYPE_AUDIO	60
EDONKEY_SUBTYPE_PLAIN	16
KUGOO	10
STUN	6
SSL_SUBTYPE_UNKOWN	2
PPLIVE	1

G) NDPI

Class	No. of Flows
unknown	179349
bittorrent	43212
skype	38918
H323	33
dns	12
ssl	2
google	1

H) Libprotoident

Class	No. of Flows
BitTorrent	210600
BitTorrent_UDP	48847
Unknown_UDP	965
Unknown_TCP	669
No_Payload	192
HTTP_NonStandard	114
Invalid_Bittorrent	81
HTTP	34
DNS	12
Gnutella_UDP	9
EMule	2
HTTPS	2

I) NBAR

Class	No. of Flows
unclassified	258805
skype	1539
h323	1014
http	147
dns	12
xwindows	2
bittorrent	2
cuseeme	2
secure-http	2
nfs	1
rsvp	1

B.2.5 Dropbox

A) PACE

Class	No. of Flows
SSL:generic:not_detected	49
unknown:no_subprotocols:not_yet_detected	36
unknown:no_subprotocols:not_detected	8

B) OpenDPI

Class	No. of Flows
SSL	49
UNKNOWN	44

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	89
FINGER	4

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	89
UNKNOWN	4

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	89
UNKNOWN	4

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	89
SKYPE_SUBTYPE_SKYPEOUT	2
UNKNOWN	2

G) NDPI

Class	No. of Flows
dropbox	80
skype	12
ssl	1

H) Libprotoident

Class	No. of Flows
HTTPS	89
HTTP	4

I) NBAR

Class	No. of Flows
secure-http	89
http	4

B.2.6 eDonkey clients (obfuscated)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	8253
eDonkey:plain:not_detected	4146
eDonkey:encrypted:not_detected	266
unknown:no_subprotocols:not_detected	169
BitTorrent:plain:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	12835

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9222
EDONKEY_SUBTYPE_PLAIN	1497
FINGER	731
NTP	651
SKYPE_SUBTYPE_SKYPEOUT	622
SKYPE_SUBTYPE_AUDIO	70
RTP	21
KUGOO	11
STUN	5
TSP	4
QQ	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	12818
KUGOO	11
STUN	5
QQ	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	12829
STUN	5
QQ	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9927
EDONKEY_SUBTYPE_PLAIN	1497
NTP	665
SKYPE_SUBTYPE_SKYPEOUT	632
SKYPE_SUBTYPE_AUDIO	72
RTP	21
KUGOO	11
STUN	5
TSP	4
QQ	1

G) NDPI

Class	No. of Flows
skype	7587
unknown	5064
rtp	184

H) Libprotoident

Class	No. of Flows
Unknown_UDP	10387
eMule_UDP	1472
Unknown_TCP	976

I) NBAR

Class	No. of Flows
unclassified	11138
rtp	1411
rtcp	232
skype	44
secure-nntp	9
cuseeme	1

B.2.7 eDonkey clients (non-obfuscated)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	12329
eDonkey:plain:not_detected	1339
eDonkey:encrypted:not_detected	140
unknown:no_subprotocols:not_detected	41
SSL:generic:not_detected	2
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	13582
EDONKEY	267
SSL	2
HTTP	1

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9107
EDONKEY_SUBTYPE_PLAIN	2487
FINGER	796
NTP	717
SKYPE_SUBTYPE_SKYPEOUT	639
SKYPE_SUBTYPE_AUDIO	62
RTP	13
KUGOO	10
TSP	9
STUN	7
QQ	3
SSL_SUBTYPE_UNKOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	13830
KUGOO	10
STUN	7
QQ	3
SSL_SUBTYPE_UNKOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	13840
STUN	7
QQ	3
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9875
EDONKEY_SUBTYPE_PLAIN	2487
NTP	733
SKYPE_SUBTYPE_SKYPEOUT	650
SKYPE_SUBTYPE_AUDIO	62
RTP	14
KUGOO	10
TSP	9
STUN	7
QQ	3
SSL_SUBTYPE_UNKOWN	2

G) NDPI

Class	No. of Flows
skype	7424
unknown	6256
rtp	118
edonkey	48
H323	3
google	1
http	1
ssl	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	10838
eMule_UDP	1893
EMule	571
Unknown_TCP	495
BitTorrent	42
HTTP	8
HTTPS	2
No_Payload	2
Skype	1

I) NBAR

Class	No. of Flows
unclassified	12001
rtp	1215
edonkey	289
rtcp	262
skype	57
h323	8
http	8
cuseeme	6
secure-nntp	3
secure-http	2
xwindows	1

B.2.8 Freenet

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_detected	115
unknown:no_subprotocols:not_yet_detected	20

B) OpenDPI

Class	No. of Flows
UNKNOWN	135

C) L7-filter-all

Class	No. of Flows
UNKNOWN	109
FINGER	9
SKYPE_SUBTYPE_SKYPEOUT	8
NTP	6
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
SKYPE_SUBTYPE_AUDIO	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	133
KUGOO	1
QQ	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	134
QQ	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	117
SKYPE_SUBTYPE_SKYPEOUT	9
NTP	6
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
unknown	114
skype	20
rtp	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	135

I) NBAR

Class	No. of Flows
unclassified	114
rtp	16
skype	3
rtcp	2

B.2.9 FTP clients (active)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_detected	117
unknown:no_subprotocols:not_yet_detected	7
FTP:control:not_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	66
FTP	60

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	120
UNKNOWN	4
FINGER	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	126

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	126

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	120
UNKNOWN	6

G) NDPI

Class	No. of Flows
unknown	66
ftp	60

H) Libprotoident

Class	No. of Flows
FTP_Data	119
FTP_Control	7

I) NBAR

Class	No. of Flows
unclassified	119
ftp	7

B.2.10 FTP clients (passive)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_detected	87
unknown:no_subprotocols:not_yet_detected	33
FTP:control:not_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	120
FTP	2

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	87
UNKNOWN	30
FINGER	3
NTP	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	122

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	122

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	87
UNKNOWN	33
NTP	2

G) NDPI

Class	No. of Flows
skype	120
unknown	2

H) Libprotoident

Class	No. of Flows
FTP_Data	84
BitTorrent	28
FTP_Control	6
No_Payload	2
Unknown_TCP	2

I) NBAR

Class	No. of Flows
unclassified	116
ftp	6

B.2.11 iTunes

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	133
SSL:generic:not_detected	69
unknown:no_subprotocols:not_detected	33

B) OpenDPI

Class	No. of Flows
UNKNOWN	166
SSL	69

C) L7-filter-all

Class	No. of Flows
FINGER	166
SSL_SUBTYPE_UNKOWN	69

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	166
SSL_SUBTYPE_UNKOWN	69

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	166
SSL_SUBTYPE_UNKOWN	69

F) L7-filter-com

Class	No. of Flows
UNKNOWN	166
SSL_SUBTYPE_UNKOWN	69

G) NDPI

Class	No. of Flows
skype	166
unknown	38
ssl	31

H) Libprotoident

Class	No. of Flows
HTTP	166
HTTPS	69

I) NBAR

Class	No. of Flows
http	166
secure-http	69

B.2.12 League of Legends

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	14
unknown:no_subprotocols:not_detected	6
SSL:generic:not_detected	3

B) OpenDPI

Class	No. of Flows
UNKNOWN	20
SSL	3

C) L7-filter-all

Class	No. of Flows
FINGER	16
UNKNOWN	4
SSL_SUBTYPE_UNKOWN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	20
SSL_SUBTYPE_UNKOWN	3

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	20
SSL_SUBTYPE_UNKOWN	3

F) L7-filter-com

Class	No. of Flows
UNKNOWN	20
SSL_SUBTYPE_UNKOWN	3

G) NDPI

Class	No. of Flows
skype	11
unknown	7
H323	2
ssl_no_cert	2
ssl	1

H) Libprotoident

Class	No. of Flows
HTTP	16
HTTPS	3
Unknown_UDP	2
ApplePush	1
SSL/TLS	1

I) NBAR

Class	No. of Flows
http	16
unclassified	4
secure-http	3

B.2.13 Pando Media Booster

A) PACE

Class	No. of Flows
Pando:no_subprotocols:not_detected	13143
unknown:no_subprotocols:not_yet_detected	306
SSL:generic:not_detected	2
STUN:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
PANDO	13143
UNKNOWN	306
SSL	2
STUN	2

C) L7-filter-all

Class	No. of Flows
UNKNOWN	13345
NTP	53
FINGER	25
TSP	17
SKYPE_SUBTYPE_SKYPEOUT	13

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	13452
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	13452
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	13370
NTP	53
TSP	17
SKYPE_SUBTYPE_SKYPEOUT	13

G) NDPI

Class	No. of Flows
skype	7242
unknown	6207
ssl_no_cert	2
stun	2

H) Libprotoident

Class	No. of Flows
Pando	13331
BitTorrent	53
HTTP	28
Pando_UDP	22
No_Payload	13
HTTP_NonStandard	2
SSL/TLS	2
STUN	2

I) NBAR

Class	No. of Flows
unclassified	13405
http	30
h323	13
mgcp	3
fasttrack	1
sap	1

B.2.14 PPLive

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	809
PPLIVE:no_subprotocols:not_detected	687
unknown:no_subprotocols:not_detected	12
STUN:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	1508
STUN	2

C) L7-filter-all

Class	No. of Flows
FINGER	686
UNKNOWN	664
SKYPE_SUBTYPE_SKYPEOUT	99
NTP	23
XUNLEI	11
KUGOO	11
EDONKEY_SUBTYPE_PLAIN	8
SKYPE_SUBTYPE_AUDIO	7
RTP	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1488
KUGOO	11
XUNLEI	11

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1510

F) L7-filter-com

Class	No. of Flows
UNKNOWN	1349
SKYPE_SUBTYPE_SKYPEOUT	100
NTP	23
KUGOO	11
XUNLEI	11
EDONKEY_SUBTYPE_PLAIN	8
SKYPE_SUBTYPE_AUDIO	7
RTP	1

G) NDPI

Class	No. of Flows
skype	1362
unknown	143
rtp	2
stun	2
Viber	1

H) Libprotoident

Class	No. of Flows
HTTP	723
PPLive	675
Unknown_UDP	109
STUN	2
No_Payload	1

I) NBAR

Class	No. of Flows
http	723
unclassified	666
rtp	113
rtcp	4
skype	3
novadigm	1

B.2.15 PPStream

A) PACE

Class	No. of Flows
PPSTREAM:no_subprotocols:not_detected	723
unknown:no_subprotocols:not_yet_detected	359
unknown:no_subprotocols:not_detected	59

B) OpenDPI

Class	No. of Flows
UNKNOWN	1132
PPSTREAM	9

C) L7-filter-all

Class	No. of Flows
UNKNOWN	704
FINGER	266
SKYPE_SUBTYPE_SKYPEOUT	90
NTP	35
TSP	28
XUNLEI	18

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1123
XUNLEI	18

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1141

F) L7-filter-com

Class	No. of Flows
UNKNOWN	970
SKYPE_SUBTYPE_SKYPEOUT	90
NTP	35
TSP	28
XUNLEI	18

G) NDPI

Class	No. of Flows
skype	1019
unknown	120
Viber	1
ppstream	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	1011
HTTP	119
PPStream	11

I) NBAR

Class	No. of Flows
unclassified	941
http	119
rtp	81

B.2.16 RDP clients

A) PACE

Class	No. of Flows
RDP:no_subprotocols:not_detected	151483
unknown:no_subprotocols:not_yet_detected	2345
unknown:no_subprotocols:not_detected	9

B) OpenDPI

Class	No. of Flows
RDP	151495
UNKNOWN	2342

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	153279
UNKNOWN	558

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	153837

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	153837

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	153279
UNKNOWN	558

G) NDPI

Class	No. of Flows
rdp	147924
skype	3724
H323	1744
unknown	445

H) Libprotoident

Class	No. of Flows
RDP	153312
No_Payload	451
Unknown_TCP	57
BitTorrent	10
RTMP	7

I) NBAR

Class	No. of Flows
unclassified	153079
h323	336
novadigm	117
mgcp	85
sap	81
citrix	58
sqlnet	29
socks	28
fasttrack	21
vdolive	2
pcanywhere	1

B.2.17 Skype

A) PACE

Class	No. of Flows
Skype:unknown:not_detected	1183
SSL:generic:not_detected	570
unknown:no_subprotocols:not_yet_detected	315
unknown:no_subprotocols:not_detected	70
Skype:voice:not_detected	26
Skype:video:not_detected	12
SSL:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	1606
SSL	571

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	1043
UNKNOWN	490
SSL_SUBTYPE_UNKOWN	385
FINGER	154
EDONKEY_SUBTYPE_PLAIN	35
RTP	28
NTP	23
SKYPE_SUBTYPE_SKYPEOUT	10
QQ	4
KUGOO	3
STUN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1771
SSL_SUBTYPE_UNKOWN	387
QQ	12
KUGOO	5
STUN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1776
SSL_SUBTYPE_UNKOWN	387
QQ	12
STUN	2

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	1044
UNKNOWN	643
SSL_SUBTYPE_UNKOWN	385
EDONKEY_SUBTYPE_PLAIN	35
RTP	28
NTP	23
SKYPE_SUBTYPE_SKYPEOUT	10
QQ	4
KUGOO	3
STUN	2

G) NDPI

Class	No. of Flows
skype	2001
ssl_no_cert	83
unknown	78
google	14
ssl	1

H) Libprotoident

Class	No. of Flows
Skype	1086
HTTPS	709
Unknown_TCP	232
HTTP	136
Unknown_UDP	13
SSL/TLS	1

I) NBAR

Class	No. of Flows
secure-http	706
skype	690
unclassified	571
http	136
rtp	63
rtcp	5
novadigm	4
h323	2

B.2.18 Skype (audio)

A) PACE

Class	No. of Flows
Skype:voice:not_detected	7

B) OpenDPI

Class	No. of Flows
UNKNOWN	7

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	6
FINGER	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	7

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	7

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

G) NDPI

Class	No. of Flows
skype	7

H) Libprotoident

Class	No. of Flows
Unknown_UDP	4
Skype	3

I) NBAR

Class	No. of Flows
skype	7

B.2.19 Skype (file transfer)

A) PACE

Class	No. of Flows
Skype:voice:not_detected	6

B) OpenDPI

Class	No. of Flows
UNKNOWN	6

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	5
QQ	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	5
QQ	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	5
QQ	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	5
QQ	1

G) NDPI

Class	No. of Flows
skype	6

H) Libprotoident

Class	No. of Flows
Unknown_UDP	5
Skype	1

I) NBAR

Class	No. of Flows
skype	6

B.2.20 Skype (video)

A) PACE

Class	No. of Flows
Skype:voice:not_detected	7

B) OpenDPI

Class	No. of Flows
UNKNOWN	7

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	5
QQ	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	5
QQ	2

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

G) NDPI

Class	No. of Flows
skype	7

H) Libprotoident

Class	No. of Flows
Skype	6
Unknown_UDP	1

I) NBAR

Class	No. of Flows
skype	7

B.2.21 Sopcast

A) PACE

Class	No. of Flows
SOPCAST:no_subprotocols:not_detected	281
unknown:no_subprotocols:not_yet_detected	141
SSL:generic:not_detected	1
unknown:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
SOPCAST	281
UNKNOWN	142
SSL	1

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	291
FINGER	103
XUNLEI	19
TSP	5
UNKNOWN	3
SKYPE_SUBTYPE_AUDIO	1
SSL_SUBTYPE_UNKOWN	1
STUN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	402
XUNLEI	19
PPLIVE	1
SSL_SUBTYPE_UNKOWN	1
STUN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	422
SSL_SUBTYPE_UNKOWN	1
STUN	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	291
UNKNOWN	106
XUNLEI	19
TSP	5
SKYPE_SUBTYPE_AUDIO	1
SSL_SUBTYPE_UNKOWN	1
STUN	1

G) NDPI

Class	No. of Flows
sopcast	281
skype	119
google	18
unknown	6

H) Libprotoident

Class	No. of Flows
Sopcast	198
HTTP	139
Unknown_UDP	82
Unknown_TCP	3
HTTPS	1
Skype	1

I) NBAR

Class	No. of Flows
http	139
skype	125
unclassified	87
rtp	72
secure-http	1

B.2.22 Spotify

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	95
unknown:no_subprotocols:not_detected	74
SSL:generic:not_detected	9

B) OpenDPI

Class	No. of Flows
UNKNOWN	169
SSL	9

C) L7-filter-all

Class	No. of Flows
UNKNOWN	93
FINGER	59
SKYPE_SUBTYPE_SKYPEOUT	8
SKYPE_SUBTYPE_AUDIO	6
NTP	5
SSL_SUBTYPE_UNKOWN	3
XUNLEI	1
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
TSP	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	167
SSL_SUBTYPE_UNKOWN	9
KUGOO	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	169
SSL_SUBTYPE_UNKOWN	9

F) L7-filter-com

Class	No. of Flows
UNKNOWN	152
SKYPE_SUBTYPE_SKYPEOUT	8
SKYPE_SUBTYPE_AUDIO	6
NTP	5
SSL_SUBTYPE_UNKOWN	3
XUNLEI	1
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
TSP	1

G) NDPI

Class	No. of Flows
skype	145
unknown	26
ssl	6
Spotify	1

H) Libprotoident

Class	No. of Flows
Unknown_TCP	100
HTTP	64
HTTPS	9
No_Payload	4
Spotify	1

I) NBAR

Class	No. of Flows
unclassified	104
http	64
secure-http	9
h323	1

B.2.23 Steam

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	716
Steam:no_subprotocols:not_detected	386
unknown:no_subprotocols:not_detected	90
SSL:generic:not_detected	10
HTTP:generic:not_detected	3

B) OpenDPI

Class	No. of Flows
UNKNOWN	1192
SSL	6
STEAM	4
HTTP	3

C) L7-filter-all

Class	No. of Flows
FINGER	746
UNKNOWN	402
SKYPE_SUBTYPE_SKYPEOUT	48
SSL_SUBTYPE_UNKOWN	7
NTP	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1195
SSL_SUBTYPE_UNKOWN	10

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1195
SSL_SUBTYPE_UNKOWN	10

F) L7-filter-com

Class	No. of Flows
UNKNOWN	1142
SKYPE_SUBTYPE_SKYPEOUT	54
SSL_SUBTYPE_UNKOWN	7
NTP	2

G) NDPI

Class	No. of Flows
skype	623
unknown	576
http	3
steam	3

H) Libprotoident

Class	No. of Flows
Steam_Friends	505
Steam_UDP	405
HTTP	279
HTTPS	10
Steam_TCP	4
Unknown_TCP	2

I) NBAR

Class	No. of Flows
unclassified	910
http	279
secure-http	9
rtp	6
h323	1

B.2.24 TOR

A) PACE

Class	No. of Flows
SSL:generic:not_detected	179
DNS:no_subprotocols:not_detected	6

B) OpenDPI

Class	No. of Flows
SSL	179
DNS	6

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	6

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	6

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	6

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	6

G) NDPI

Class	No. of Flows
skype	160
ssl	13
Tor	6
dns	6

H) Libprotoident

Class	No. of Flows
HTTPS	91
TOR	62
SSL/TLS	26
Unknown_UDP	4
DNS	2

I) NBAR

Class	No. of Flows
unclassified	91
secure-http	87
dns	6
h323	1

B.2.25 World of Warcraft

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	22

B) OpenDPI

Class	No. of Flows
UNKNOWN	22

C) L7-filter-all

Class	No. of Flows
FINGER	14
SKYPE_SUBTYPE_SKYPEOUT	5
UNKNOWN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	22

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	22

F) L7-filter-com

Class	No. of Flows
UNKNOWN	17
SKYPE_SUBTYPE_SKYPEOUT	5

G) NDPI

Class	No. of Flows
skype	11
unknown	10
google	1

H) Libprotoident

Class	No. of Flows
HTTP	19
WorldOfWarcraft	3

I) NBAR

Class	No. of Flows
http	19
unclassified	3

B.3 Web Services

B.3.1 4Shared

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	87
unknown:no_subprotocols:not_detected	8
HTTP:generic:not_yet_detected	2
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	95
HTTP	2
SSL	1

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	64
FINGER	23
UNKNOWN	7
SSL_SUBTYPE_UNKOWN	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	94
SSL_SUBTYPE_UNKOWN	4

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	94
SSL_SUBTYPE_UNKOWN	4

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	64
UNKNOWN	30
SSL_SUBTYPE_UNKOWN	4

G) NDPI

Class	No. of Flows
skype	80
unknown	12
http	6

H) Libprotoident

Class	No. of Flows
HTTP	87
No_Payload	7
HTTPS	4

I) NBAR

Class	No. of Flows
http	87
unclassified	7
secure-http	4

B.3.2 Amazon

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	436
SSL:generic:not_detected	118
SSL:generic:not_yet_detected	26
unknown:no_subprotocols:not_detected	21
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	463
SSL	138
HTTP	1

C) L7-filter-all

Class	No. of Flows
FINGER	251
SKYPE_SUBTYPE_SKYPEOUT	165
UNKNOWN	94
SSL_SUBTYPE_UNKOWN	84
XUNLEI	8

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	431
SSL_SUBTYPE_UNKOWN	143
XUNLEI	28

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	459
SSL_SUBTYPE_UNKOWN	143

F) L7-filter-com

Class	No. of Flows
UNKNOWN	292
SKYPE_SUBTYPE_SKYPEOUT	218
SSL_SUBTYPE_UNKOWN	84
XUNLEI	8

G) NDPI

Class	No. of Flows
unknown	321
skype	209
ssl	69
ssl_no_cert	2
http	1

H) Libprotoident

Class	No. of Flows
HTTP	360
HTTPS	148
No_Payload	89
BitTorrent	5

I) NBAR

Class	No. of Flows
http	365
secure-http	148
unclassified	89

B.3.3 Apple

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	437
unknown:no_subprotocols:not_detected	37
SSL:generic:not_detected	2
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	476
HTTP	1

C) L7-filter-all

Class	No. of Flows
FINGER	356
UNKNOWN	79
SKYPE_SUBTYPE_SKYPEOUT	21
SSL_SUBTYPE_UNKOWN	21

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	452
SSL_SUBTYPE_UNKOWN	21
XUNLEI	4

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	456
SSL_SUBTYPE_UNKOWN	21

F) L7-filter-com

Class	No. of Flows
UNKNOWN	430
SKYPE_SUBTYPE_SKYPEOUT	26
SSL_SUBTYPE_UNKOWN	21

G) NDPI

Class	No. of Flows
skype	249
unknown	204
http	16
Apple	6
H323	2

H) Libprotoident

Class	No. of Flows
HTTP	377
No_Payload	79
HTTPS	21

I) NBAR

Class	No. of Flows
http	377
unclassified	79
secure-http	21

B.3.4 Ask

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	160
unknown:no_subprotocols:not_detected	10
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	170
HTTP	1

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	96
FINGER	73
UNKNOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	171

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	171

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	96
UNKNOWN	75

G) NDPI

Class	No. of Flows
skype	156
unknown	14
http	1

H) Libprotoident

Class	No. of Flows
HTTP	169
No_Payload	2

I) NBAR

Class	No. of Flows
http	169
unclassified	2

B.3.5 Bing

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	394
unknown:no_subprotocols:not_detected	58
HTTP:generic:not_yet_detected	2
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	452
HTTP	2
SSL	2

C) L7-filter-all

Class	No. of Flows
FINGER	427
UNKNOWN	23
SKYPE_SUBTYPE_SKYPEOUT	4
SSL_SUBTYPE_UNKOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	450
XUNLEI	4
SSL_SUBTYPE_UNKOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	454
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	422
SKYPE_SUBTYPE_SKYPEOUT	32
SSL_SUBTYPE_UNKOWN	2

G) NDPI

Class	No. of Flows
unknown	280
skype	171
http	4
ssl	1

H) Libprotoident

Class	No. of Flows
HTTP	431
No_Payload	23
HTTPS	2

I) NBAR

Class	No. of Flows
http	431
unclassified	23
secure-http	2

B.3.6 Blogspot

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	201
unknown:no_subprotocols:not_detected	13
HTTP:generic:not_yet_detected	12
SSL:generic:not_detected	9

B) OpenDPI

Class	No. of Flows
UNKNOWN	222
HTTP	12
SSL	1

C) L7-filter-all

Class	No. of Flows
FINGER	200
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	10
SKYPE_SUBTYPE_SKYPEOUT	6
SKYPE_SUBTYPE_AUDIO	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	224
SSL_SUBTYPE_UNKOWN	11

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	224
SSL_SUBTYPE_UNKOWN	11

F) L7-filter-com

Class	No. of Flows
UNKNOWN	218
SSL_SUBTYPE_UNKOWN	10
SKYPE_SUBTYPE_SKYPEOUT	6
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
google	219
skype	15
unknown	1

H) Libprotoident

Class	No. of Flows
HTTP	206
No_Payload	18
HTTPS	11

I) NBAR

Class	No. of Flows
http	206
unclassified	18
secure-http	11

B.3.7 CNN

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	218
unknown:no_subprotocols:not_detected	26
HTTP:generic:not_yet_detected	2
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	244
HTTP	2
SSL	1

C) L7-filter-all

Class	No. of Flows
FINGER	216
UNKNOWN	24
SKYPE_SUBTYPE_SKYPEOUT	5
SSL_SUBTYPE_UNKOWN	1
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	245
SSL_SUBTYPE_UNKOWN	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	246
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	240
SKYPE_SUBTYPE_SKYPEOUT	5
SSL_SUBTYPE_UNKOWN	1
XUNLEI	1

G) NDPI

Class	No. of Flows
skype	160
unknown	85
http	2

H) Libprotoident

Class	No. of Flows
HTTP	222
No_Payload	24
HTTPS	1

I) NBAR

Class	No. of Flows
http	222
unclassified	24
secure-http	1

B.3.8 Craigslist

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	176
HTTP:generic:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
UNKNOWN	176
HTTP	3

C) L7-filter-all

Class	No. of Flows
FINGER	161
UNKNOWN	15
SKYPE_SUBTYPE_SKYPEOUT	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	179

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	179

F) L7-filter-com

Class	No. of Flows
UNKNOWN	176
SKYPE_SUBTYPE_SKYPEOUT	3

G) NDPI

Class	No. of Flows
unknown	176
http	3

H) Libprotoident

Class	No. of Flows
HTTP	164
No_Payload	15

I) NBAR

Class	No. of Flows
http	164
unclassified	15

B.3.9 Cyworld

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	303
unknown:no_subprotocols:not_detected	23
FLASH:no_subprotocols:not_detected	3
HTTP:generic:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
UNKNOWN	326
FLASH	3
HTTP	3

C) L7-filter-all

Class	No. of Flows
FINGER	171
SKYPE_SUBTYPE_SKYPEOUT	90
UNKNOWN	67
KUGOO	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	328
KUGOO	4

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	332

F) L7-filter-com

Class	No. of Flows
UNKNOWN	238
SKYPE_SUBTYPE_SKYPEOUT	90
KUGOO	4

G) NDPI

Class	No. of Flows
skype	190
unknown	136
flash	3
http	3

H) Libprotoident

Class	No. of Flows
HTTP	272
No_Payload	57
RTMP	3

I) NBAR

Class	No. of Flows
http	272
unclassified	60

B.3.10 Doubleclick

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	1938
unknown:no_subprotocols:not_detected	34
SSL:generic:not_detected	17

B) OpenDPI

Class	No. of Flows
UNKNOWN	1982
SSL	7

C) L7-filter-all

Class	No. of Flows
FINGER	1567
UNKNOWN	279
SKYPE_SUBTYPE_SKYPEOUT	110
SSL_SUBTYPE_UNKOWN	27
SKYPE_SUBTYPE_AUDIO	6

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1957
SSL_SUBTYPE_UNKOWN	32

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1957
SSL_SUBTYPE_UNKOWN	32

F) L7-filter-com

Class	No. of Flows
UNKNOWN	1686
SKYPE_SUBTYPE_SKYPEOUT	270
SSL_SUBTYPE_UNKOWN	27
SKYPE_SUBTYPE_AUDIO	6

G) NDPI

Class	No. of Flows
google	1892
skype	60
unknown	37

H) Libprotoident

Class	No. of Flows
HTTP	1676
No_Payload	272
HTTPS	40
BitTorrent	1

I) NBAR

Class	No. of Flows
http	1674
unclassified	275
secure-http	40

B.3.11 eBay

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	270
unknown:no_subprotocols:not_detected	7
SSL:generic:not_detected	2
HTTP:generic:not_detected	1
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	277
HTTP	2
SSL	2

C) L7-filter-all

Class	No. of Flows
FINGER	197
UNKNOWN	81
SSL_SUBTYPE_UNKOWN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	274
XUNLEI	4
SSL_SUBTYPE_UNKOWN	3

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	278
SSL_SUBTYPE_UNKOWN	3

F) L7-filter-com

Class	No. of Flows
UNKNOWN	208
SKYPE_SUBTYPE_SKYPEOUT	70
SSL_SUBTYPE_UNKOWN	3

G) NDPI

Class	No. of Flows
unknown	262
skype	15
http	2
ssl	2

H) Libprotoident

Class	No. of Flows
HTTP	197
No_Payload	77
HTTPS	7

I) NBAR

Class	No. of Flows
http	197
unclassified	77
secure-http	7

B.3.12 Facebook

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	6045
unknown:no_subprotocols:not_detected	818
SSL:generic:not_detected	77
SSL:generic:not_yet_detected	6
HTTP:generic:not_detected	5
HTTP:generic:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	6891
SSL	55
HTTP	7

C) L7-filter-all

Class	No. of Flows
FINGER	5335
UNKNOWN	1145
SKYPE_SUBTYPE_SKYPEOUT	303
SSL_SUBTYPE_UNKOWN	150
QQ	14
SKYPE_SUBTYPE_AUDIO	6

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	6148
XUNLEI	641
SSL_SUBTYPE_UNKOWN	150
QQ	14

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	6789
SSL_SUBTYPE_UNKOWN	150
QQ	14

F) L7-filter-com

Class	No. of Flows
UNKNOWN	5304
SKYPE_SUBTYPE_SKYPEOUT	1403
SSL_SUBTYPE_UNKOWN	150
XUNLEI	76
QQ	14
SKYPE_SUBTYPE_AUDIO	6

G) NDPI

Class	No. of Flows
unknown	5353
skype	1491
http	91
ssl	12
H323	6

H) Libprotoident

Class	No. of Flows
HTTP	5637
No_Payload	1123
HTTPS	192
BitTorrent	1

I) NBAR

Class	No. of Flows
http	5611
unclassified	1150
secure-http	192

B.3.13 Go.com

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	289
unknown:no_subprotocols:not_detected	34
SSL:generic:not_detected	8
HTTP:generic:not_yet_detected	4

B) OpenDPI

Class	No. of Flows
UNKNOWN	331
HTTP	4

C) L7-filter-all

Class	No. of Flows
FINGER	246
UNKNOWN	43
SKYPE_SUBTYPE_SKYPEOUT	37
SSL_SUBTYPE_UNKOWN	8
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	326
SSL_SUBTYPE_UNKOWN	8
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	327
SSL_SUBTYPE_UNKOWN	8

F) L7-filter-com

Class	No. of Flows
UNKNOWN	289
SKYPE_SUBTYPE_SKYPEOUT	37
SSL_SUBTYPE_UNKOWN	8
XUNLEI	1

G) NDPI

Class	No. of Flows
unknown	200
skype	109
http	26

H) Libprotoident

Class	No. of Flows
HTTP	284
No_Payload	43
HTTPS	8

I) NBAR

Class	No. of Flows
http	276
unclassified	48
secure-http	8
h323	3

B.3.14 Google

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	5019
unknown:no_subprotocols:not_detected	767
SSL:generic:not_detected	596
HTTP:generic:not_yet_detected	108
SSL:generic:not_yet_detected	51

B) OpenDPI

Class	No. of Flows
UNKNOWN	5999
SSL	434
HTTP	108

C) L7-filter-all

Class	No. of Flows
FINGER	3529
UNKNOWN	1271
SKYPE_SUBTYPE_SKYPEOUT	824
SSL_SUBTYPE_UNKOWN	800
SKYPE_SUBTYPE_AUDIO	93
QQ	23
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	5616
SSL_SUBTYPE_UNKOWN	875
XUNLEI	26
QQ	23
NBNS	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	5642
SSL_SUBTYPE_UNKOWN	875
QQ	23
NBNS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	4221
SKYPE_SUBTYPE_SKYPEOUT	1401
SSL_SUBTYPE_UNKOWN	800
SKYPE_SUBTYPE_AUDIO	93
QQ	23
XUNLEI	2
NBNS	1

G) NDPI

Class	No. of Flows
google	4847
unknown	1164
skype	479
http	47
ssl	2
H323	1
ssl_no_cert	1

H) Libprotoident

Class	No. of Flows
HTTP	4352
HTTPS	1292
No_Payload	892
BitTorrent	5

I) NBAR

Class	No. of Flows
http	4354
secure-http	1294
unclassified	893

B.3.15 Instagram

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	7
HTTP:generic:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	7
HTTP	2

C) L7-filter-all

Class	No. of Flows
FINGER	7
SKYPE_SUBTYPE_SKYPEOUT	1
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	9

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	9

F) L7-filter-com

Class	No. of Flows
UNKNOWN	8
SKYPE_SUBTYPE_SKYPEOUT	1

G) NDPI

Class	No. of Flows
skype	6
http	2
unknown	1

H) Libprotoident

Class	No. of Flows
HTTP	8
No_Payload	1

I) NBAR

Class	No. of Flows
http	8
unclassified	1

B.3.16 Justin.tv

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	2194
unknown:no_subprotocols:not_detected	126
HTTP:generic:not_yet_detected	6

B) OpenDPI

Class	No. of Flows
UNKNOWN	2320
HTTP	6

C) L7-filter-all

Class	No. of Flows
FINGER	1660
XUNLEI	309
UNKNOWN	278
SKYPE_SUBTYPE_SKYPEOUT	79

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1971
XUNLEI	355

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	2326

F) L7-filter-com

Class	No. of Flows
UNKNOWN	1668
SKYPE_SUBTYPE_SKYPEOUT	349
XUNLEI	309

G) NDPI

Class	No. of Flows
unknown	1383
skype	923
http	20

H) Libprotoident

Class	No. of Flows
HTTP	1963
No_Payload	278
HTTP_NonStandard	77
BitTorrent	7
HTTP_443	1

I) NBAR

Class	No. of Flows
http	1978
unclassified	281
secure-http	67

B.3.17 LinkedIn

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	54
unknown:no_subprotocols:not_detected	5
SSL:generic:not_detected	2
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	59
SSL	2
HTTP	1

C) L7-filter-all

Class	No. of Flows
FINGER	33
SSL_SUBTYPE_UNKOWN	18
UNKNOWN	9
SKYPE_SUBTYPE_SKYPEOUT	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	44
SSL_SUBTYPE_UNKOWN	18

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	44
SSL_SUBTYPE_UNKOWN	18

F) L7-filter-com

Class	No. of Flows
UNKNOWN	40
SSL_SUBTYPE_UNKOWN	18
SKYPE_SUBTYPE_SKYPEOUT	4

G) NDPI

Class	No. of Flows
skype	34
unknown	24
http	4

H) Libprotoident

Class	No. of Flows
HTTP	35
HTTPS	18
No_Payload	9

I) NBAR

Class	No. of Flows
http	35
secure-http	18
unclassified	9

B.3.18 Mediafire

A) PACE

Class	No. of Flows
SSL:generic:not_detected	326
unknown:no_subprotocols:not_yet_detected	121
unknown:no_subprotocols:not_detected	23
HTTP:generic:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	470
HTTP	2

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	326
FINGER	122
SKYPE_SUBTYPE_SKYPEOUT	21
UNKNOWN	2
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	326
UNKNOWN	145
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	326
UNKNOWN	146

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	326
UNKNOWN	124
SKYPE_SUBTYPE_SKYPEOUT	21
XUNLEI	1

G) NDPI

Class	No. of Flows
skype	467
http	3
unknown	2

H) Libprotoident

Class	No. of Flows
HTTPS	326
HTTP	144
No_Payload	2

I) NBAR

Class	No. of Flows
secure-http	326
http	144
unclassified	2

B.3.19 MSN

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	913
unknown:no_subprotocols:not_detected	7
HTTP:generic:not_yet_detected	5
HTTP:generic:not_detected	3

B) OpenDPI

Class	No. of Flows
UNKNOWN	920
HTTP	8

C) L7-filter-all

Class	No. of Flows
FINGER	666
UNKNOWN	225
SKYPE_SUBTYPE_SKYPEOUT	37

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	879
XUNLEI	49

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	928

F) L7-filter-com

Class	No. of Flows
UNKNOWN	749
SKYPE_SUBTYPE_SKYPEOUT	178
XUNLEI	1

G) NDPI

Class	No. of Flows
unknown	564
skype	353
http	11

H) Libprotoident

Class	No. of Flows
HTTP	701
No_Payload	222
HTTPS	3
BitTorrent	2

I) NBAR

Class	No. of Flows
http	703
unclassified	222
secure-http	3

B.3.20 MySpace

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
FINGER	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	2

G) NDPI

Class	No. of Flows
skype	2

H) Libprotoident

Class	No. of Flows
HTTP	2

I) NBAR

Class	No. of Flows
http	2

B.3.21 Pinterest

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	177
unknown:no_subprotocols:not_detected	5
SSL:generic:not_yet_detected	4
SSL:generic:not_detected	2
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	187
HTTP	1
SSL	1

C) L7-filter-all

Class	No. of Flows
FINGER	123
SKYPE_SUBTYPE_SKYPEOUT	32
UNKNOWN	23
SSL_SUBTYPE_UNKOWN	7
XUNLEI	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	178
SSL_SUBTYPE_UNKOWN	7
XUNLEI	4

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	182
SSL_SUBTYPE_UNKOWN	7

F) L7-filter-com

Class	No. of Flows
UNKNOWN	143
SKYPE_SUBTYPE_SKYPEOUT	35
SSL_SUBTYPE_UNKOWN	7
XUNLEI	4

G) NDPI

Class	No. of Flows
unknown	118
skype	68
http	3

H) Libprotoident

Class	No. of Flows
HTTP	159
No_Payload	23
HTTPS	7

I) NBAR

Class	No. of Flows
http	159
unclassified	23
secure-http	7

B.3.22 Putlocker

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	85
unknown:no_subprotocols:not_detected	15
SSL:generic:not_yet_detected	2
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	102
HTTP	1

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	44
FINGER	43
UNKNOWN	12
SSL_SUBTYPE_UNKOWN	2
XUNLEI	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	99
SSL_SUBTYPE_UNKOWN	2
XUNLEI	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	101
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	55
SKYPE_SUBTYPE_SKYPEOUT	44
SSL_SUBTYPE_UNKOWN	2
XUNLEI	2

G) NDPI

Class	No. of Flows
skype	87
unknown	14
http	2

H) Libprotoident

Class	No. of Flows
HTTP	89
No_Payload	12
HTTPS	2

I) NBAR

Class	No. of Flows
http	75
secure-http	16
unclassified	12

B.3.23 QQ.com

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	741
unknown:no_subprotocols:not_detected	8
HTTP:generic:not_yet_detected	4

B) OpenDPI

Class	No. of Flows
UNKNOWN	750
HTTP	3

C) L7-filter-all

Class	No. of Flows
FINGER	432
SKYPE_SUBTYPE_SKYPEOUT	188
UNKNOWN	132
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	752
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	753

F) L7-filter-com

Class	No. of Flows
UNKNOWN	561
SKYPE_SUBTYPE_SKYPEOUT	191
XUNLEI	1

G) NDPI

Class	No. of Flows
unknown	514
skype	233
http	6

H) Libprotoident

Class	No. of Flows
HTTP	620
No_Payload	111
Unknown_TCP	21
BitTorrent	1

I) NBAR

Class	No. of Flows
http	642
unclassified	111

B.3.24 Taobao

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	345
unknown:no_subprotocols:not_detected	39
HTTP:generic:not_yet_detected	1
SSL:generic:not_detected	1
SSL:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	386
HTTP	1

C) L7-filter-all

Class	No. of Flows
FINGER	336
UNKNOWN	29
SKYPE_SUBTYPE_SKYPEOUT	20
SSL_SUBTYPE_UNKOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	385
SSL_SUBTYPE_UNKOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	385
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	365
SKYPE_SUBTYPE_SKYPEOUT	20
SSL_SUBTYPE_UNKOWN	2

G) NDPI

Class	No. of Flows
unknown	174
skype	170
http	43

H) Libprotoident

Class	No. of Flows
HTTP	355
No_Payload	29
HTTPS	2
BitTorrent	1

I) NBAR

Class	No. of Flows
http	356
unclassified	29
secure-http	2

B.3.25 The Huffington Post

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	55
unknown:no_subprotocols:not_detected	15
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	70
HTTP	1

C) L7-filter-all

Class	No. of Flows
FINGER	53
SKYPE_SUBTYPE_SKYPEOUT	12
UNKNOWN	4
XUNLEI	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	69
XUNLEI	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	71

F) L7-filter-com

Class	No. of Flows
UNKNOWN	57
SKYPE_SUBTYPE_SKYPEOUT	12
XUNLEI	2

G) NDPI

Class	No. of Flows
unknown	59
skype	10
H323	1
http	1

H) Libprotoident

Class	No. of Flows
HTTP	67
No_Payload	4

I) NBAR

Class	No. of Flows
http	67
unclassified	4

B.3.26 Tumblr

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	346
unknown:no_subprotocols:not_detected	57

B) OpenDPI

Class	No. of Flows
UNKNOWN	403

C) L7-filter-all

Class	No. of Flows
FINGER	351
UNKNOWN	46
SKYPE_SUBTYPE_SKYPEOUT	5
SSL_SUBTYPE_UNKOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	397
XUNLEI	4
KUGOO	1
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	402
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	372
SKYPE_SUBTYPE_SKYPEOUT	29
KUGOO	1
SSL_SUBTYPE_UNKOWN	1

G) NDPI

Class	No. of Flows
unknown	320
skype	68
http	15

H) Libprotoident

Class	No. of Flows
HTTP	356
No_Payload	36
HTTPS	11

I) NBAR

Class	No. of Flows
http	354
unclassified	38
secure-http	11

B.3.27 Twitter

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	922
SSL:generic:not_detected	126
SSL:generic:not_yet_detected	67
unknown:no_subprotocols:not_detected	23

B) OpenDPI

Class	No. of Flows
UNKNOWN	1054
SSL	84

C) L7-filter-all

Class	No. of Flows
UNKNOWN	355
FINGER	338
SSL_SUBTYPE_UNKOWN	190
SKYPE_SUBTYPE_SKYPEOUT	131
XUNLEI	107
SKYPE_SUBTYPE_AUDIO	17

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	833
SSL_SUBTYPE_UNKOWN	198
XUNLEI	107

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	940
SSL_SUBTYPE_UNKOWN	198

F) L7-filter-com

Class	No. of Flows
UNKNOWN	636
SSL_SUBTYPE_UNKOWN	190
SKYPE_SUBTYPE_SKYPEOUT	188
XUNLEI	107
SKYPE_SUBTYPE_AUDIO	17

G) NDPI

Class	No. of Flows
unknown	892
skype	153
ssl	54
ssl_no_cert	21
http	18

H) Libprotoident

Class	No. of Flows
HTTP	576
No_Payload	307
HTTPS	255

I) NBAR

Class	No. of Flows
http	576
unclassified	307
secure-http	255

B.3.28 Vimeo

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	95
unknown:no_subprotocols:not_detected	28
SSL:generic:not_detected	7
SSL:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	131

C) L7-filter-all

Class	No. of Flows
FINGER	67
SSL_SUBTYPE_UNKOWN	37
UNKNOWN	23
SKYPE_SUBTYPE_SKYPEOUT	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	94
SSL_SUBTYPE_UNKOWN	37

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	94
SSL_SUBTYPE_UNKOWN	37

F) L7-filter-com

Class	No. of Flows
UNKNOWN	88
SSL_SUBTYPE_UNKOWN	37
SKYPE_SUBTYPE_SKYPEOUT	6

G) NDPI

Class	No. of Flows
skype	68
unknown	59
ssl_no_cert	3
http	1

H) Libprotoident

Class	No. of Flows
HTTP	71
HTTPS	40
No_Payload	20

I) NBAR

Class	No. of Flows
http	71
secure-http	40
unclassified	20

B.3.29 VK.com

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	336
unknown:no_subprotocols:not_detected	6
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	342
HTTP	1

C) L7-filter-all

Class	No. of Flows
FINGER	322
SKYPE_SUBTYPE_SKYPEOUT	12
UNKNOWN	9

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	343

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	343

F) L7-filter-com

Class	No. of Flows
UNKNOWN	331
SKYPE_SUBTYPE_SKYPEOUT	12

G) NDPI

Class	No. of Flows
unknown	210
skype	132
http	1

H) Libprotoident

Class	No. of Flows
HTTP	334
No_Payload	9

I) NBAR

Class	No. of Flows
http	334
unclassified	9

B.3.30 Wikipedia

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	5715
unknown:no_subprotocols:not_detected	356
SSL:generic:not_detected	15
SSL:generic:not_yet_detected	5
Skype:unknown:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	6091
SSL	1

C) L7-filter-all

Class	No. of Flows
FINGER	4161
UNKNOWN	1882
SSL_SUBTYPE_UNKOWN	25
SKYPE_SUBTYPE_SKYPEOUT	24

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	6067
SSL_SUBTYPE_UNKOWN	25

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	6067
SSL_SUBTYPE_UNKOWN	25

F) L7-filter-com

Class	No. of Flows
UNKNOWN	5787
SKYPE_SUBTYPE_SKYPEOUT	280
SSL_SUBTYPE_UNKOWN	25

G) NDPI

Class	No. of Flows
unknown	6043
skype	29
ssl_no_cert	17
Whois_Das	1
http	1
ssl	1

H) Libprotoident

Class	No. of Flows
HTTP	4182
No_Payload	1856
HTTPS	35
Unknown_TCP	17
BitTorrent	2

I) NBAR

Class	No. of Flows
http	4201
unclassified	1856
secure-http	35

B.3.31 Windows Live

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	10
HTTP:generic:not_yet_detected	8
SSL:generic:not_detected	8

B) OpenDPI

Class	No. of Flows
UNKNOWN	10
HTTP	8
SSL	8

C) L7-filter-all

Class	No. of Flows
FINGER	17
SSL_SUBTYPE_UNKOWN	8
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	8

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	8

F) L7-filter-com

Class	No. of Flows
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	8

G) NDPI

Class	No. of Flows
skype	13
http	8
unknown	5

H) Libprotoident

Class	No. of Flows
HTTP	17
HTTPS	8
No_Payload	1

I) NBAR

Class	No. of Flows
http	17
secure-http	8
unclassified	1

B.3.32 Wordpress

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	130
unknown:no_subprotocols:not_detected	28
SSL:generic:not_detected	5
HTTP:generic:not_yet_detected	4
SSL:generic:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	165
HTTP	4

C) L7-filter-all

Class	No. of Flows
FINGER	131
UNKNOWN	19
SKYPE_SUBTYPE_SKYPEOUT	12
SSL_SUBTYPE_UNKOWN	7

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	162
SSL_SUBTYPE_UNKOWN	7

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	162
SSL_SUBTYPE_UNKOWN	7

F) L7-filter-com

Class	No. of Flows
UNKNOWN	147
SKYPE_SUBTYPE_SKYPEOUT	15
SSL_SUBTYPE_UNKOWN	7

G) NDPI

Class	No. of Flows
unknown	121
skype	44
http	4

H) Libprotoident

Class	No. of Flows
HTTP	143
No_Payload	19
HTTPS	7

I) NBAR

Class	No. of Flows
http	143
unclassified	19
secure-http	7

B.3.33 Yahoo

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	16522
unknown:no_subprotocols:not_detected	598
HTTP:generic:not_yet_detected	133
FLASH:no_subprotocols:not_detected	80
SSL:generic:not_detected	33
SSL:generic:not_yet_detected	4
FLASH:no_subprotocols:not_yet_detected	2
HTTP:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	17120
HTTP	134
FLASH	82
SSL	37

C) L7-filter-all

Class	No. of Flows
FINGER	14226
UNKNOWN	2531
SKYPE_SUBTYPE_SKYPEOUT	536
SSL_SUBTYPE_UNKOWN	66
XUNLEI	8
TSP	4
QQ	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	16913
XUNLEI	392
SSL_SUBTYPE_UNKOWN	66
QQ	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	17305
SSL_SUBTYPE_UNKOWN	66
QQ	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	15797
SKYPE_SUBTYPE_SKYPEOUT	1421
XUNLEI	83
SSL_SUBTYPE_UNKOWN	66
TSP	4
QQ	2

G) NDPI

Class	No. of Flows
unknown	9753
skype	7385
http	137
flash	71
ssl	17
ssl_no_cert	5
H323	3
Whois_Das	2

H) Libprotoident

Class	No. of Flows
HTTP	14482
No_Payload	2311
YahooError	410
RTMP	81
HTTPS	67
Unknown_TCP	21
Web_Junk	1

I) NBAR

Class	No. of Flows
http	13918
unclassified	3388
secure-http	67

B.3.34 YouTube

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	2090
unknown:no_subprotocols:not_detected	409
SSL:generic:not_detected	31
HTTP:generic:not_yet_detected	2
SSL:generic:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	2506
SSL	26
HTTP	2

C) L7-filter-all

Class	No. of Flows
FINGER	1928
UNKNOWN	374
SKYPE_SUBTYPE_SKYPEOUT	145
SSL_SUBTYPE_UNKOWN	66
SKYPE_SUBTYPE_AUDIO	10
QQ	6
XUNLEI	5

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	2448
SSL_SUBTYPE_UNKOWN	73
QQ	6
XUNLEI	6
KUGOO	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	2455
SSL_SUBTYPE_UNKOWN	73
QQ	6

F) L7-filter-com

Class	No. of Flows
UNKNOWN	2156
SKYPE_SUBTYPE_SKYPEOUT	289
SSL_SUBTYPE_UNKOWN	66
SKYPE_SUBTYPE_AUDIO	10
QQ	6
XUNLEI	6
KUGOO	1

G) NDPI

Class	No. of Flows
google	1918
unknown	321
skype	291
H323	4

H) Libprotoident

Class	No. of Flows
HTTP	2077
No_Payload	342
HTTPS	109
BitTorrent	6

I) NBAR

Class	No. of Flows
http	2076
unclassified	349
secure-http	109

Appendix C

Dataset with Truncated Flows – Detailed Results

This section presents the detailed insight into the classification results performed on the dataset with truncated flows. The correct results are makred in green, wrong in red, while the unclassified items are left in black.

C.1 Application Protocols

C.1.1 DNS

A) PACE

Class	No. of Flows
DNS:no_subprotocols:not_detected	18242
unknown:no_subprotocols:not_yet_detected	9

B) OpenDPI

Class	No. of Flows
DNS	18249
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
DNS	18182
UNKNOWN	60
FINGER	6
SKYPE_SUBTYPE_SKYPEOUT	2
EDONKEY_SUBTYPE_PLAIN	1

D) L7-filter-sel

Class	No. of Flows
DNS	18182
UNKNOWN	69

E) L7-filter-aut

Class	No. of Flows
DNS	18182
UNKNOWN	69

F) L7-filter-com

Class	No. of Flows
DNS	18182
UNKNOWN	66
SKYPE_SUBTYPE_SKYPEOUT	2
EDONKEY_SUBTYPE_PLAIN	1

G) NDPI

Class	No. of Flows
dns	18250
unknown	1

H) Libprotoident

Class	No. of Flows
DNS	18243
Unknown_UDP	7
Unknown_TCP	1

I) NBAR

Class	No. of Flows
dns	18249
citrix	1
unclassified	1

C.1.2 HTTP

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	19881
Yahoo:webmail:not_detected	9464
HTTP:generic:facebook	5422
HTTP:generic:not_yet_detected	1997
HTTP:generic:youtube	1725
PPLIVE:no_subprotocols:not_detected	567
HTTP:generic:twitter	555
HTTP:media:not_detected	496
unknown:no_subprotocols:not_yet_detected	309
FLASH:no_subprotocols:not_detected	295
Steam:no_subprotocols:not_detected	279
FLASH:no_subprotocols:youtube	271
BitTorrent:plain:not_detected	267
QQLive:no_subprotocols:not_detected	242
HTTP:generic:ebay	214
HTTP:generic:amazon_cloud	153
DirectDownloadLink:mediafire.com:not_detected	143
HTTP:generic:itunes	127
DirectDownloadLink:4shared.com:not_detected	122
HTTP:generic:amazon_shop	57
MEEBO:unknown:not_detected	52
Yahoo:unknown:not_detected	43
Socks:socksv5:not_yet_detected	38
HTTP:generic:linkedin	30
Pando:no_subprotocols:not_detected	30
QUICKTIME:no_subprotocols:itunes	28
QUICKTIME:no_subprotocols:not_detected	28
WINDOWSMEDIA:no_subprotocols:windowsmedia	28
HTTP:video:youtube	18
HTTP:generic:hotmail_webmail	12
QUICKTIME:no_subprotocols:youtube	9
MPEG:no_subprotocols:facebook	9
MPEG:no_subprotocols:youtube	8
HTTP:generic:instagram	8
FLASH:no_subprotocols:facebook	7
HTTP:generic:gmail	7
HTTP:generic:live_com	5
HTTP:video:not_detected	5
HTTP:generic:flickr	5
Spotify:no_subprotocols:amazon_cloud	4
WINDOWSMEDIA:no_subprotocols:youtube	4
Yahoo:webchat:not_detected	4
World of Warcraft:no_subprotocols:not_detected	3
PPSTREAM:no_subprotocols:not_detected	3
eDonkey:plain:not_detected	3
HTTP:generic:myspace	2
WebDAV:no_subprotocols:not_detected	2
HTTP:media:youtube	1
WINDOWSMEDIA:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	41382
FLASH	590
UNKNOWN	489
DIRECT_DOWNLOAD_LINK	264
BITTORRENT	251
QUICKTIME	115
WINDOWSMEDIA	32
EDONKEY	3
MPEG	1

C) L7-filter-all

Class	No. of Flows
FINGER	36996
SKYPE_SUBTYPE_SKYPEOUT	3572
HTTP_SUBTYPE_UNKNOWN	1530
XUNLEI	790
ITUNES	152
SOULSEEK	53
UNKNOWN	12
HTTP_SUBTYPE_CACHEHIT	12
KUGOO	4
ARMAGETRON	3
EDONKEY_SUBTYPE_PLAIN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	25209
HTTP_SUBTYPE_UNKNOWN	14396
HTTP_SUBTYPE_CACHEHIT	2389
XUNLEI	790
ITUNES	152
HTTP_SUBTYPE_VIDEO	77
SOULSEEK	53
HTTP_SUBTYPE_CHACHEMISS	45
KUGOO	6
HTTP_SUBTYPE_AUDIO	4
ARMAGETRON	3
NBNS	1
PPLIVE	1
SOCKS	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	20412
HTTP_SUBTYPE_UNKNOWN	12348
FACEBOOK	5440
HTTP_SUBTYPE_CACHEHIT	2382
YOUTUBE	1564
TWITTER	554
ITUNES	152
BITTORRENT_SUBTYPE_PLAIN	120
SOULSEEK	53
HTTP_SUBTYPE_VIDEO	48
HTTP_SUBTYPE_CHACHEMISS	45
HTTP_SUBTYPE_AUDIO	4
ARMAGETRON	3
NBNS	1
SOCKS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	23452
HTTP_SUBTYPE_UNKNOWN	12611
SKYPE_SUBTYPE_SKYPEOUT	3576
HTTP_SUBTYPE_CACHEHIT	2353
XUNLEI	790
ITUNES	152
HTTP_SUBTYPE_VIDEO	77
SOULSEEK	53
HTTP_SUBTYPE_CHACHEMISS	44
KUGOO	6
HTTP_SUBTYPE_AUDIO	4
ARMAGETRON	3
EDONKEY_SUBTYPE_PLAIN	3
NBNS	1
PPLIVE	1
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
http	35403
google	6723
facebook	590
yahoo	157
skype	141
youtube	48
twitter	27
Apple	13
unknown	10
http_connect	8
dropbox	4
edonkey	3

H) Libprotoident

Class	No. of Flows
HTTP	42736
HTTP_NonStandard	303
SOCKS5	53
BitTorrent	26
EMule	3
Web_Junk	3
No_Payload	2
HTTP_443	1

I) NBAR

Class	No. of Flows
http	42174
unclassified	876
secure-http	67
edonkey	3
h323	3
bittorrent	2
irc	2

C.1.3 ICMP

A) PACE

Class	No. of Flows
ICMP:no_subprotocols:not_detected	205

B) OpenDPI

Class	No. of Flows
ICMP	205

C) L7-filter-all

Class	No. of Flows
UNKNOWN	205

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	205

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	205

F) L7-filter-com

Class	No. of Flows
UNKNOWN	205

G) NDPI

Class	No. of Flows
icmp	205

H) Libprotoident

Class	No. of Flows
ICMP	205

I) NBAR

Class	No. of Flows
icmp	203
unclassified	2

C.1.4 IMAP-STARTTLS

A) PACE

Class	No. of Flows
IMAP:no_subprotocols:not_detected	35

B) OpenDPI

Class	No. of Flows
MAIL_IMAP	35

C) L7-filter-all

Class	No. of Flows
MAIL_IMAP	35

D) L7-filter-sel

Class	No. of Flows
MAIL_IMAP	35

E) L7-filter-aut

Class	No. of Flows
MAIL_IMAP	35

F) L7-filter-com

Class	No. of Flows
MAIL_IMAP	35

G) NDPI

Class	No. of Flows
imap	35

H) Libprotoident

Class	No. of Flows
IMAP	35

I) NBAR

Class	No. of Flows
imap	35

C.1.5 IMAP-TLS

A) PACE

Class	No. of Flows
SSL:generic:gmail	103

B) OpenDPI

Class	No. of Flows
SSL	103

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	103

G) NDPI

Class	No. of Flows
google	103

H) Libprotoident

Class	No. of Flows
IMAPS	103

I) NBAR

Class	No. of Flows
secure-imap	103

C.1.6 NETBIOS Name Service

A) PACE

Class	No. of Flows
NETBIOS:no_subprotocols:not_detected	10195
unknown:no_subprotocols:not_yet_detected	4

B) OpenDPI

Class	No. of Flows
NETBIOS	10047
UNKNOWN	152

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9265
SKYPE_SUBTYPE_SKYPEOUT	446
EDONKEY_SUBTYPE_PLAIN	258
NTP	118
RTP	111
FINGER	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	10199

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	10199

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9266
SKYPE_SUBTYPE_SKYPEOUT	446
EDONKEY_SUBTYPE_PLAIN	258
NTP	118
RTP	111

G) NDPI

Class	No. of Flows
netbios	10199

H) Libprotoident

Class	No. of Flows
Unknown_UDP	9691
RTP	502
NetBIOS_UDP	4
Kademlia	1
eMule_UDP	1

I) NBAR

Class	No. of Flows
netbios	10199

C.1.7 NETBIOS Session Service

A) PACE

Class	No. of Flows
NETBIOS:no_subprotocols:not_detected	11

B) OpenDPI

Class	No. of Flows
NETBIOS	11

C) L7-filter-all

Class	No. of Flows
UNKNOWN	10
SMB	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	10
SMB	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	10
SMB	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	10
SMB	1

G) NDPI

Class	No. of Flows
netbios	11

H) Libprotoident

Class	No. of Flows
NetBIOS	11

I) NBAR

Class	No. of Flows
netbios	11

C.1.8 SAMBA Session Service

A) PACE

Class	No. of Flows
SMB/CIFS:no_subprotocols:not_detected	42808

B) OpenDPI

Class	No. of Flows
SMB	42808

C) L7-filter-all

Class	No. of Flows
SMB	42807
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
SMB	42807
UNKNOWN	1

E) L7-filter-aut

Class	No. of Flows
SMB	42807
UNKNOWN	1

F) L7-filter-com

Class	No. of Flows
SMB	42807
UNKNOWN	1

G) NDPI

Class	No. of Flows
smb	42808

H) Libprotoident

Class	No. of Flows
SMB	42808

I) NBAR

Class	No. of Flows
unclassified	42806
pcanywhere	2

C.1.9 NTP

A) PACE

Class	No. of Flows
NTP:no_subprotocols:not_detected	42227

B) OpenDPI

Class	No. of Flows
NTP	42227

C) L7-filter-all

Class	No. of Flows
NTP	42166
EDONKEY_SUBTYPE_PLAIN	52
UNKNOWN	6
QQ	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	42195
QQ	32

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	42195
QQ	32

F) L7-filter-com

Class	No. of Flows
NTP	42166
EDONKEY_SUBTYPE_PLAIN	52
UNKNOWN	6
QQ	3

G) NDPI

Class	No. of Flows
ntp	42227

H) Libprotoident

Class	No. of Flows
NTP	42227

I) NBAR

Class	No. of Flows
unclassified	42227

C.1.10 POP3-PLAIN

A) PACE

Class	No. of Flows
POP:no_subprotocols:not_detected	26

B) OpenDPI

Class	No. of Flows
MAIL_POP	26

C) L7-filter-all

Class	No. of Flows
MAIL_POP	26

D) L7-filter-sel

Class	No. of Flows
MAIL_POP	26

E) L7-filter-aut

Class	No. of Flows
MAIL_POP	26

F) L7-filter-com

Class	No. of Flows
MAIL_POP	26

G) NDPI

Class	No. of Flows
pop	26

H) Libprotoident

Class	No. of Flows
POP3	26

I) NBAR

Class	No. of Flows
pop3	26

C.1.11 POP3-TLS

A) PACE

Class	No. of Flows
SSL:generic:not_detected	101

B) OpenDPI

Class	No. of Flows
SSL	101

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	95
FINGER	5
SKYPE_SUBTYPE_SKYPEOUT	1

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	95
UNKNOWN	6

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	95
UNKNOWN	6

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	95
UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	1

G) NDPI

Class	No. of Flows
ssl_no_cert	88
google	12
pops	1

H) Libprotoident

Class	No. of Flows
POP3S	101

I) NBAR

Class	No. of Flows
secure-pop3	101

C.1.12 RTMP

A) PACE

Class	No. of Flows
FLASH:no_subprotocols:not_yet_detected	309
unknown:no_subprotocols:not_yet_detected	43
FLASH:no_subprotocols:not_detected	26

B) OpenDPI

Class	No. of Flows
FLASH	335
UNKNOWN	43

C) L7-filter-all

Class	No. of Flows
UNKNOWN	289
SKYPE_SUBTYPE_SKYPEOUT	50
TSP	36
H323	1
PPLIVE	1
SKYPE_SUBTYPE_AUDIO	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	376
H323	1
PPLIVE	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	377
H323	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	289
SKYPE_SUBTYPE_SKYPEOUT	50
TSP	36
H323	1
PPLIVE	1
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
flash	320
unknown	42
H323	16

H) Libprotoident

Class	No. of Flows
RTMP	324
No_Payload	40
Unknown_TCP	11
SSL/TLS	2
BitTorrent	1

I) NBAR

Class	No. of Flows
unclassified	377
mgcp	1

C.1.13 SMTP-PLAIN

A) PACE

Class	No. of Flows
SMTP:no_subprotocols:not_detected	67

B) OpenDPI

Class	No. of Flows
MAIL_SMTP	67

C) L7-filter-all

Class	No. of Flows
MAIL_SMTP	67

D) L7-filter-sel

Class	No. of Flows
MAIL_SMTP	67

E) L7-filter-aut

Class	No. of Flows
MAIL_SMTP	67

F) L7-filter-com

Class	No. of Flows
MAIL_SMTP	67

G) NDPI

Class	No. of Flows
unknown	67

H) Libprotoident

Class	No. of Flows
SMTP	67

I) NBAR

Class	No. of Flows
smtp	67

C.1.14 SMTP-TLS

A) PACE

Class	No. of Flows
SSL:generic:gmail	50
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
SSL	52

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	52

G) NDPI

Class	No. of Flows
google	50
ssl_no_cert	2

H) Libprotoident

Class	No. of Flows
SMTP_Secure	52

I) NBAR

Class	No. of Flows
unclassified	52

C.1.15 SOCKSv5

A) PACE

Class	No. of Flows
Socks:socksv5:not_yet_detected	1734
BitTorrent:plain:not_detected	68
Socks:socksv5:facebook	47
Google:encrypted:not_yet_detected	43
Socks:socksv5:twitter	13
HTTP:generic:not_yet_detected	11
unknown:no_subprotocols:twitter	5
unknown:no_subprotocols:facebook	2
unknown:no_subprotocols:not_yet_detected	2
SSL:generic:not_detected	1
SSL:generic:twitter	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	1927

C) L7-filter-all

Class	No. of Flows
SOULSEEK	1927

D) L7-filter-sel

Class	No. of Flows
SOULSEEK	1927

E) L7-filter-aut

Class	No. of Flows
SOULSEEK	1927

F) L7-filter-com

Class	No. of Flows
SOULSEEK	1927

G) NDPI

Class	No. of Flows
skype	1927

H) Libprotoident

Class	No. of Flows
SOCKS5	1927

I) NBAR

Class	No. of Flows
unclassified	1927

C.1.16 SSH

A) PACE

Class	No. of Flows
SSH:no_subprotocols:not_detected	36615
unknown:no_subprotocols:not_yet_detected	2033
SSL:generic:not_detected	97
SSL:generic:facebook	68
Google:encrypted:not_detected	57
BitTorrent:plain:not_detected	47
SPDY:ssl:not_detected	14
SPDY:ssl:facebook	11
SSL:generic:twitter	8
SPDY:ssl:twitter	5
SSL:generic:not_yet_detected	4
unknown:no_subprotocols:facebook	1
unknown:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
SSH	36615
UNKNOWN	2036
SSL	263
BITTORRENT	47

C) L7-filter-all

Class	No. of Flows
SSH	36697
UNKNOWN	1918
SSL_SUBTYPE_UNKOWN	193
FINGER	93
BITTORRENT_SUBTYPE_PLAIN	47
SSL_SUBTYPE_VALIDCERTSSL	12
NTP	1

D) L7-filter-sel

Class	No. of Flows
SSH	36697
UNKNOWN	2012
SSL_SUBTYPE_UNKOWN	193
BITTORRENT_SUBTYPE_PLAIN	47
SSL_SUBTYPE_VALIDCERTSSL	12

E) L7-filter-aut

Class	No. of Flows
SSH	36697
UNKNOWN	2012
SSL_SUBTYPE_UNKOWN	193
BITTORRENT_SUBTYPE_PLAIN	47
SSL_SUBTYPE_VALIDCERTSSL	12

F) L7-filter-com

Class	No. of Flows
SSH	36697
UNKNOWN	2011
SSL_SUBTYPE_UNKOWN	193
BITTORRENT_SUBTYPE_PLAIN	47
SSL_SUBTYPE_VALIDCERTSSL	12
NTP	1

G) NDPI

Class	No. of Flows
ssh	36615
unknown	2107
ssl_no_cert	173
bittorrent	47
ssl	12
skype	7

H) Libprotoident

Class	No. of Flows
SSH	36697
No_Payload	1851
HTTPS	272
HTTP	93
BitTorrent	47
Unknown_TCP	1

I) NBAR

Class	No. of Flows
ssh	36516
unclassified	1940
secure-http	272
h323	107
http	77
bittorrent	47
socks	1
xwindows	1

C.1.17 Webdav

A) PACE

Class	No. of Flows
SSL:generic:not_detected	55
WebDAV:no_subprotocols:not_detected	2

B) OpenDPI

Class	No. of Flows
SSL	55
HTTP	2

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	53
RTP	2
SKYPE_SUBTYPE_SKYPEOUT	2

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	55
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	55
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	53
RTP	2
SKYPE_SUBTYPE_SKYPEOUT	2

G) NDPI

Class	No. of Flows
skype	55
http_connect	2

H) Libprotoident

Class	No. of Flows
HTTPS	55
HTTP	2

I) NBAR

Class	No. of Flows
secure-http	55
http	2

C.2 Applications

C.2.1 4Shared

A) PACE

Class	No. of Flows
SSL:generic:not_detected	105
DirectDownloadLink:4shared.com:not_detected	39

B) OpenDPI

Class	No. of Flows
SSL	105
DIRECT_DOWNLOAD_LINK	39

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
HTTP_SUBTYPE_UNKNOWN	37
FINGER	2

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
HTTP_SUBTYPE_UNKNOWN	37
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
HTTP_SUBTYPE_UNKNOWN	37
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	105
HTTP_SUBTYPE_UNKNOWN	37
UNKNOWN	2

G) NDPI

Class	No. of Flows
skype	105
http	39

H) Libprotoident

Class	No. of Flows
HTTPS	105
HTTP	39

I) NBAR

Class	No. of Flows
secure-http	105
unclassified	37
http	2

C.2.2 America's Army

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	350

B) OpenDPI

Class	No. of Flows
UNKNOWN	350

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	316
RTP	16
FINGER	8
UNKNOWN	8
NTP	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	350

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	350

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	323
RTP	16
UNKNOWN	9
NTP	2

G) NDPI

Class	No. of Flows
unknown	200
skype	141
TeamSpeak	9

H) Libprotoident

Class	No. of Flows
Steam_UDP	284
Unknown_UDP	38
HalfLife	28

I) NBAR

Class	No. of Flows
rtp	226
unclassified	123
rtcp	1

C.2.3 BitTorrent clients (encrypted)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	32088
BitTorrent:plain:not_detected	32018
BitTorrent:uTP:not_detected	26251
BitTorrent:encrypted:not_detected	5922
unknown:no_subprotocols:not_detected	68
eDonkey:encrypted:not_detected	41
DNS:no_subprotocols:not_detected	10
HTTP:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	96139
BITTORRENT	236
HTTP	14
DNS	10

C) L7-filter-all

Class	No. of Flows
UNKNOWN	47716
BITTORRENT_SUBTYPE_PLAIN	38912
SKYPE_SUBTYPE_SKYPEOUT	3389
FINGER	2875
NTP	1653
EDONKEY_SUBTYPE_PLAIN	814
KUGOO	406
SKYPE_SUBTYPE_AUDIO	263
QQ	184
RTP	125
SSL_SUBTYPE_UNKOWN	18
HTTP_SUBTYPE_UNKNOWN	15
TSP	13
DNS	10
NBNS	4
PPLIVE	1
SOULSEEK	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	56720
BITTORRENT_SUBTYPE_PLAIN	38929
KUGOO	425
QQ	196
HTTP_SUBTYPE_UNKNOWN	95
SSL_SUBTYPE_UNKOWN	18
DNS	10
NBNS	4
PPLIVE	1
SOULSEEK	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	57144
BITTORRENT_SUBTYPE_PLAIN	38991
QQ	196
HTTP_SUBTYPE_UNKNOWN	35
SSL_SUBTYPE_UNKOWN	18
DNS	10
NBNS	4
SOULSEEK	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	50404
BITTORRENT_SUBTYPE_PLAIN	38913
SKYPE_SUBTYPE_SKYPEOUT	3423
NTP	1692
EDONKEY_SUBTYPE_PLAIN	830
KUGOO	411
SKYPE_SUBTYPE_AUDIO	269
QQ	185
RTP	129
HTTP_SUBTYPE_UNKNOWN	95
SSL_SUBTYPE_UNKOWN	18
TSP	14
DNS	10
NBNS	4
SOULSEEK	1
PPLIVE	1

G) NDPI

Class	No. of Flows
bittorrent	51751
skype	22825
unknown	21687
http	126
dns	10

H) Libprotoident

Class	No. of Flows
BitTorrent_UDP	57987
Unknown_TCP	36874
Unknown_UDP	1289
HTTP_NonStandard	110
No_Payload	76
HTTP	16
BitTorrent	14
DNS	10
RTMP	7
Gnutella_UDP	6
Invalid_Bittorrent	6
Web_Junk	2
Xunlei	1
Mystery_8000	1

I) NBAR

Class	No. of Flows
unclassified	95231
bittorrent	900
h323	182
http	69
dns	10
pcanywhere	3
sqlserver	1
edonkey	1
nfs	1
rsvp	1

C.2.4 BitTorrent clients (non-encrypted)

A) PACE

Class	No. of Flows
BitTorrent:plain:not_detected	240450
BitTorrent:uTP:not_detected	20384
unknown:no_subprotocols:not_yet_detected	474
BitTorrent:encrypted:not_detected	191
DNS:no_subprotocols:not_detected	12
HTTP:generic:not_detected	9
eDonkey:encrypted:not_detected	2
eDonkey:plain:not_detected	2
HTTP:generic:amazon_cloud	1
SSL:generic:amazon_cloud	1
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
BITTORRENT	210769
UNKNOWN	50715
HTTP	27
DNS	12
EDONKEY	2
SSL	2

C) L7-filter-all

Class	No. of Flows
BITTORRENT_SUBTYPE_PLAIN	247060
UNKNOWN	13206
SKYPE_SUBTYPE_SKYPEOUT	779
FINGER	178
QQ	142
SKYPE_SUBTYPE_AUDIO	61
NTP	42
HTTP_SUBTYPE_UNKNOWN	17
EDONKEY_SUBTYPE_PLAIN	16
DNS	12
KUGOO	10
STUN	2
RTP	1
SSL_SUBTYPE_UNKOWN	1

D) L7-filter-sel

Class	No. of Flows
BITTORRENT_SUBTYPE_PLAIN	247067
UNKNOWN	14188
QQ	147
HTTP_SUBTYPE_UNKNOWN	100
DNS	12
KUGOO	10
STUN	2
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
BITTORRENT_SUBTYPE_PLAIN	247125
UNKNOWN	14189
QQ	147
HTTP_SUBTYPE_UNKNOWN	51
DNS	12
STUN	2
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
BITTORRENT_SUBTYPE_PLAIN	247060
UNKNOWN	13301
SKYPE_SUBTYPE_SKYPEOUT	779
QQ	143
HTTP_SUBTYPE_UNKNOWN	99
SKYPE_SUBTYPE_AUDIO	61
NTP	42
EDONKEY_SUBTYPE_PLAIN	16
DNS	12
KUGOO	10
STUN	2
SSL_SUBTYPE_UNKOWN	1
RTP	1

G) NDPI

Class	No. of Flows
bittorrent	254783
skype	6170
unknown	410
http	147
dns	12
edonkey	2
ssl_no_cert	2
google	1

H) Libprotoident

Class	No. of Flows
BitTorrent	210601
BitTorrent_UDP	48847
Unknown_UDP	965
Unknown_TCP	669
No_Payload	195
HTTP_NonStandard	114
Invalid_Bittorrent	77
HTTP	34
DNS	12
Gnutella_UDP	9
EMule	2
HTTPS	2

I) NBAR

Class	No. of Flows
unclassified	191423
bittorrent	69727
h323	278
http	77
dns	12
secure-http	2
edonkey	2
pptp	2
rsvp	1
xwindows	1
cuseeme	1
nfs	1

C.2.5 Dropbox

A) PACE

Class	No. of Flows
SSL:generic:dropbox	88
HTTP:generic:not_detected	4
unknown:no_subprotocols:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
SSL	88
HTTP	4
UNKNOWN	1

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	60
SSL_SUBTYPE_VALIDCERTSSL	29
FINGER	4

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	60
SSL_SUBTYPE_VALIDCERTSSL	29
HTTP_SUBTYPE_UNKNOWN	2
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	60
SSL_SUBTYPE_VALIDCERTSSL	29
HTTP_SUBTYPE_UNKNOWN	2
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	60
SSL_SUBTYPE_VALIDCERTSSL	29
HTTP_SUBTYPE_UNKNOWN	2
UNKNOWN	2

G) NDPI

Class	No. of Flows
dropbox	80
skype	12
ssl_no_cert	1

H) Libprotoident

Class	No. of Flows
HTTPS	89
HTTP	4

I) NBAR

Class	No. of Flows
secure-http	89
http	4

C.2.6 eDonkey clients (obfuscated)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	7476
eDonkey:plain:not_detected	4535
BitTorrent:encrypted:not_detected	686
unknown:no_subprotocols:not_detected	137
eDonkey:encrypted:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	12835

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9213
EDONKEY_SUBTYPE_PLAIN	1494
FINGER	729
NTP	656
SKYPE_SUBTYPE_SKYPEOUT	615
SKYPE_SUBTYPE_AUDIO	74
RTP	37
KUGOO	11
TSP	4
QQ	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	12822
KUGOO	11
QQ	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	12833
QQ	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9918
EDONKEY_SUBTYPE_PLAIN	1494
NTP	670
SKYPE_SUBTYPE_SKYPEOUT	623
SKYPE_SUBTYPE_AUDIO	76
RTP	37
KUGOO	11
TSP	4
QQ	2

G) NDPI

Class	No. of Flows
skype	7587
unknown	5064
rtp	184

H) Libprotoident

Class	No. of Flows
Unknown_UDP	10387
eMule_UDP	1472
Unknown_TCP	976

I) NBAR

Class	No. of Flows
unclassified	12356
rtp	390
rtcp	43
skype	35
secure-nntp	11

C.2.7 eDonkey clients (non-obfuscated)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	7180
eDonkey:plain:not_detected	6263
BitTorrent:encrypted:not_detected	310
unknown:no_subprotocols:not_detected	47
BitTorrent:plain:not_detected	42
HTTP:generic:not_detected	8
Google:encrypted:not_detected	1
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	13261
EDONKEY	541
BITTORRENT	42
HTTP	6
SSL	2

C) L7-filter-all

Class	No. of Flows
UNKNOWN	9102
EDONKEY_SUBTYPE_PLAIN	2487
FINGER	793
NTP	677
SKYPE_SUBTYPE_SKYPEOUT	642
SKYPE_SUBTYPE_AUDIO	61
BITTORRENT_SUBTYPE_PLAIN	42
RTP	24
TSP	10
KUGOO	10
SSL_SUBTYPE_UNKOWN	2
STUN	1
QQ	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	13793
BITTORRENT_SUBTYPE_PLAIN	42
KUGOO	10
HTTP_SUBTYPE_UNKNOWN	3
SSL_SUBTYPE_UNKOWN	2
QQ	1
STUN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	13803
BITTORRENT_SUBTYPE_PLAIN	42
HTTP_SUBTYPE_UNKNOWN	3
SSL_SUBTYPE_UNKOWN	2
QQ	1
STUN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	9865
EDONKEY_SUBTYPE_PLAIN	2487
NTP	693
SKYPE_SUBTYPE_SKYPEOUT	652
SKYPE_SUBTYPE_AUDIO	61
BITTORRENT_SUBTYPE_PLAIN	42
RTP	25
TSP	10
KUGOO	10
HTTP_SUBTYPE_UNKNOWN	3
SSL_SUBTYPE_UNKOWN	2
STUN	1
QQ	1

G) NDPI

Class	No. of Flows
skype	7413
unknown	5977
edonkey	294
rtp	118
bittorrent	42
http	6
google	1
ssl_no_cert	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	10838
eMule_UDP	1893
EMule	571
Unknown_TCP	495
BitTorrent	42
HTTP	8
HTTPS	2
No_Payload	2
Skype	1

I) NBAR

Class	No. of Flows
unclassified	12846
rtp	601
edonkey	173
rtcp	139
skype	50
bittorrent	21
http	8
h323	7
secure-nntp	3
cuseeme	2
secure-http	2

C.2.8 Freenet

A) PACE

Class	No. of Flows
Freenet:no_subprotocols:not_detected	94
unknown:no_subprotocols:not_yet_detected	41

B) OpenDPI

Class	No. of Flows
UNKNOWN	135

C) L7-filter-all

Class	No. of Flows
UNKNOWN	109
FINGER	9
SKYPE_SUBTYPE_SKYPEOUT	8
NTP	6
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
SKYPE_SUBTYPE_AUDIO	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	134
KUGOO	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	135

F) L7-filter-com

Class	No. of Flows
UNKNOWN	117
SKYPE_SUBTYPE_SKYPEOUT	9
NTP	6
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
unknown	114
skype	20
rtp	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	135

I) NBAR

Class	No. of Flows
unclassified	114
rtp	18
rtcp	2
skype	1

C.2.9 FTP clients (active)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	119
FTP:control:not_detected	7

B) OpenDPI

Class	No. of Flows
UNKNOWN	119
FTP	7

C) L7-filter-all

Class	No. of Flows
SOCKS	113
FTP_SUBTYPE_CONTROL	7
UNKNOWN	3
FINGER	2
SKYPE_SUBTYPE_SKYPEOUT	1

D) L7-filter-sel

Class	No. of Flows
SOCKS	114
FTP_SUBTYPE_CONTROL	7
UNKNOWN	5

E) L7-filter-aut

Class	No. of Flows
SOCKS	114
FTP_SUBTYPE_CONTROL	7
UNKNOWN	5

F) L7-filter-com

Class	No. of Flows
SOCKS	113
FTP_SUBTYPE_CONTROL	7
UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	1

G) NDPI

Class	No. of Flows
unknown	119
ftp	7

H) Libprotoident

Class	No. of Flows
FTP_Data	119
FTP_Control	7

I) NBAR

Class	No. of Flows
unclassified	119
ftp	7

C.2.10 FTP clients (passive)

A) PACE

Class	No. of Flows
unknown:no_subprotocols:not_yet_detected	116
FTP:control:not_detected	6

B) OpenDPI

Class	No. of Flows
UNKNOWN	116
FTP	6

C) L7-filter-all

Class	No. of Flows
SOCKS	80
UNKNOWN	33
FTP_SUBTYPE_CONTROL	6
FINGER	2
SKYPE_SUBTYPE_SKYPEOUT	1

D) L7-filter-sel

Class	No. of Flows
SOCKS	81
UNKNOWN	35
FTP_SUBTYPE_CONTROL	6

E) L7-filter-aut

Class	No. of Flows
SOCKS	81
UNKNOWN	35
FTP_SUBTYPE_CONTROL	6

F) L7-filter-com

Class	No. of Flows
SOCKS	80
UNKNOWN	35
FTP_SUBTYPE_CONTROL	6
SKYPE_SUBTYPE_SKYPEOUT	1

G) NDPI

Class	No. of Flows
skype	92
unknown	30

H) Libprotoident

Class	No. of Flows
FTP_Data	83
No_Payload	30
FTP_Control	6
Unknown_TCP	2
BitTorrent	1

I) NBAR

Class	No. of Flows
unclassified	116
ftp	6

C.2.11 iTunes

A) PACE

Class	No. of Flows
HTTP:generic:itunes	125
SSL:generic:not_detected	38
SSL:generic:itunes	31
QUICKTIME:no_subprotocols:itunes	26
QUICKTIME:no_subprotocols:not_detected	15

B) OpenDPI

Class	No. of Flows
HTTP	150
SSL	69
QUICKTIME	16

C) L7-filter-all

Class	No. of Flows
ITUNES	150
UNKNOWN	33
SSL_SUBTYPE_VALIDCERTSSL	31
FINGER	16
SSL_SUBTYPE_UNKOWN	5

D) L7-filter-sel

Class	No. of Flows
ITUNES	150
UNKNOWN	49
SSL_SUBTYPE_VALIDCERTSSL	31
SSL_SUBTYPE_UNKOWN	5

E) L7-filter-aut

Class	No. of Flows
ITUNES	150
UNKNOWN	49
SSL_SUBTYPE_VALIDCERTSSL	31
SSL_SUBTYPE_UNKOWN	5

F) L7-filter-com

Class	No. of Flows
ITUNES	150
UNKNOWN	49
SSL_SUBTYPE_VALIDCERTSSL	31
SSL_SUBTYPE_UNKOWN	5

G) NDPI

Class	No. of Flows
http	164
skype	38
ssl_no_cert	31
Apple	2

H) Libprotoident

Class	No. of Flows
HTTP	166
HTTPS	69

I) NBAR

Class	No. of Flows
http	166
secure-http	69

C.2.12 League of Legends

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	13
SSL:generic:not_detected	5
FLASH:no_subprotocols:youtube	2
unknown:no_subprotocols:not_yet_detected	2
HTTP:generic:youtube	1

B) OpenDPI

Class	No. of Flows
HTTP	14
SSL	5
FLASH	2
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
FINGER	15
UNKNOWN	4
SSL_SUBTYPE_UNKOWN	2
HTTP_SUBTYPE_UNKNOWN	1
RTP	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	16
HTTP_SUBTYPE_UNKNOWN	5
SSL_SUBTYPE_UNKOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	13
HTTP_SUBTYPE_UNKNOWN	5
YOUTUBE	3
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	15
HTTP_SUBTYPE_UNKNOWN	5
SSL_SUBTYPE_UNKOWN	2
RTP	1

G) NDPI

Class	No. of Flows
http	16
ssl_no_cert	3
ssl	2
unknown	2

H) Libprotoident

Class	No. of Flows
HTTP	16
HTTPS	3
Unknown_UDP	2
ApplePush	1
SSL/TLS	1

I) NBAR

Class	No. of Flows
http	16
unclassified	4
secure-http	3

C.2.13 Pando Media Booster

A) PACE

Class	No. of Flows
Pando:no_subprotocols:not_detected	13379
BitTorrent:plain:not_detected	53
unknown:no_subprotocols:not_yet_detected	17
SSL:generic:not_detected	2
STUN:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
PANDO	13349
BITTORRENT	71
UNKNOWN	17
HTTP	12
SSL	2
STUN	2

C) L7-filter-all

Class	No. of Flows
UNKNOWN	13345
BITTORRENT_SUBTYPE_PLAIN	53
FINGER	25
TSP	17
HTTP_SUBTYPE_UNKNOWN	9
RTP	2
SKYPE_SUBTYPE_SKYPEOUT	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	13375
BITTORRENT_SUBTYPE_PLAIN	53
HTTP_SUBTYPE_UNKNOWN	24
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	13375
BITTORRENT_SUBTYPE_PLAIN	53
HTTP_SUBTYPE_UNKNOWN	24
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	13355
BITTORRENT_SUBTYPE_PLAIN	53
HTTP_SUBTYPE_UNKNOWN	24
TSP	17
RTP	2
SKYPE_SUBTYPE_SKYPEOUT	2

G) NDPI

Class	No. of Flows
unknown	13366
bittorrent	53
http	30
ssl_no_cert	2
stun	2

H) Libprotoident

Class	No. of Flows
Pando	13331
BitTorrent	53
HTTP	28
Pando_UDP	22
No_Payload	13
HTTP_NonStandard	2
SSL/TLS	2
STUN	2

I) NBAR

Class	No. of Flows
unclassified	13375
http	30
bittorrent	28
h323	13
mgcp	3
fasttrack	1
notes	1
pptp	1
sap	1

C.2.14 PPLive

A) PACE

Class	No. of Flows
PPLIVE:no_subprotocols:not_detected	1332
HTTP:generic:not_detected	110
HTTP:generic:not_yet_detected	46
unknown:no_subprotocols:not_yet_detected	20
STUN:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	784
HTTP	658
QUICKTIME	65
STUN	2
PPLIVE	1

C) L7-filter-all

Class	No. of Flows
UNKNOWN	663
FINGER	588
XUNLEI	108
SKYPE_SUBTYPE_SKYPEOUT	99
NTP	23
KUGOO	11
EDONKEY_SUBTYPE_PLAIN	8
SKYPE_SUBTYPE_AUDIO	7
HTTP_SUBTYPE_UNKNOWN	1
NBNS	1
RTP	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1359
XUNLEI	108
HTTP_SUBTYPE_UNKNOWN	31
KUGOO	11
NBNS	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1473
HTTP_SUBTYPE_UNKNOWN	36
NBNS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	1230
XUNLEI	108
SKYPE_SUBTYPE_SKYPEOUT	100
NTP	23
HTTP_SUBTYPE_UNKNOWN	21
KUGOO	11
EDONKEY_SUBTYPE_PLAIN	8
SKYPE_SUBTYPE_AUDIO	7
NBNS	1
RTP	1

G) NDPI

Class	No. of Flows
http	723
skype	674
unknown	107
rtp	2
stun	2
Viber	1
bittorrent	1

H) Libprotoident

Class	No. of Flows
HTTP	723
PPLive	675
Unknown_UDP	109
STUN	2
No_Payload	1

I) NBAR

Class	No. of Flows
unclassified	783
http	721
rtcp	5
novadigm	1

C.2.15 PPStream

A) PACE

Class	No. of Flows
PPSTREAM:no_subprotocols:not_detected	905
unknown:no_subprotocols:not_yet_detected	116
HTTP:generic:not_yet_detected	79
HTTP:generic:not_detected	31
FLASH:no_subprotocols:not_detected	6
unknown:no_subprotocols:not_detected	4

B) OpenDPI

Class	No. of Flows
UNKNOWN	1013
HTTP	113
PPSTREAM	9
FLASH	6

C) L7-filter-all

Class	No. of Flows
UNKNOWN	705
FINGER	266
SKYPE_SUBTYPE_SKYPEOUT	90
NTP	34
TSP	28
XUNLEI	18

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1105
HTTP_SUBTYPE_UNKNOWN	18
XUNLEI	18

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1123
HTTP_SUBTYPE_UNKNOWN	18

F) L7-filter-com

Class	No. of Flows
UNKNOWN	960
SKYPE_SUBTYPE_SKYPEOUT	90
NTP	34
TSP	28
XUNLEI	18
HTTP_SUBTYPE_UNKNOWN	11

G) NDPI

Class	No. of Flows
skype	918
http	119
unknown	102
Viber	1
ppstream	1

H) Libprotoident

Class	No. of Flows
Unknown_UDP	1011
HTTP	119
PPStream	11

I) NBAR

Class	No. of Flows
unclassified	942
http	119
rtp	80

C.2.16 RDP clients

A) PACE

Class	No. of Flows
RDP:no_subprotocols:not_detected	153361
unknown:no_subprotocols:not_yet_detected	476

B) OpenDPI

Class	No. of Flows
RDP	153369
UNKNOWN	468

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	141827
UNKNOWN	12000
NBNS	10

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	153827
NBNS	10

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	153827
NBNS	10

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	141827
UNKNOWN	12000
NBNS	10

G) NDPI

Class	No. of Flows
rdp	149798
skype	3571
unknown	446
H323	22

H) Libprotoident

Class	No. of Flows
RDP	153316
No_Payload	452
Unknown_TCP	54
BitTorrent	10
RTMP	5

I) NBAR

Class	No. of Flows
unclassified	152804
h323	336
novadigm	117
citrix	115
skinny	86
mgcp	85
sap	81
notes	34
l2tp	33
nfs	33
sqlnet	29
socks	28
pptp	21
fasttrack	21
sqlserver	11
vdolive	2
pcanywhere	1

C.2.17 Skype

A) PACE

Class	No. of Flows
Skype:unknown:not_detected	1160
SSL:generic:not_detected	485
unknown:no_subprotocols:not_yet_detected	181
HTTP:generic:not_detected	93
SSL:generic:facebook	90
unknown:no_subprotocols:not_detected	71
HTTP:generic:not_yet_detected	34
Skype:unknown:live_com	33
Google:encrypted:not_detected	12
Skype:out:not_detected	9
FLASH:no_subprotocols:youtube	5
FLASH:no_subprotocols:not_detected	3
HTTP:generic:youtube	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	1332
SSL	709
HTTP	128
FLASH	8

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	1036
RTP	468
UNKNOWN	224
SSL_SUBTYPE_UNKOWN	221
FINGER	154
EDONKEY_SUBTYPE_PLAIN	35
NTP	23
SKYPE_SUBTYPE_SKYPEOUT	7
QQ	6
KUGOO	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1527
SSL_SUBTYPE_UNKOWN	562
HTTP_SUBTYPE_UNKNOWN	71
QQ	11
KUGOO	5
HTTP_SUBTYPE_VIDEO	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1529
SSL_SUBTYPE_UNKOWN	562
HTTP_SUBTYPE_UNKNOWN	68
QQ	11
YOUTUBE	6
HTTP_SUBTYPE_VIDEO	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	1037
RTP	468
UNKNOWN	305
SSL_SUBTYPE_UNKOWN	221
HTTP_SUBTYPE_UNKNOWN	71
EDONKEY_SUBTYPE_PLAIN	35
NTP	23
SKYPE_SUBTYPE_SKYPEOUT	7
QQ	6
KUGOO	3
HTTP_SUBTYPE_VIDEO	1

G) NDPI

Class	No. of Flows
skype	1589
ssl_no_cert	303
ssl	137
http	134
google	14

H) Libprotoident

Class	No. of Flows
Skype	1086
HTTPS	709
Unknown_TCP	232
HTTP	136
Unknown_UDP	13
SSL/TLS	1

I) NBAR

Class	No. of Flows
secure-http	706
skype	684
unclassified	570
http	136
rtp	70
rtcp	5
novadigm	4
h323	2

C.2.18 Skype (audio)

A) PACE

Class	No. of Flows
Skype:unknown:not_detected	7

B) OpenDPI

Class	No. of Flows
UNKNOWN	7

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	6
FINGER	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	7

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	7

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

G) NDPI

Class	No. of Flows
skype	7

H) Libprotoident

Class	No. of Flows
Unknown_UDP	4
Skype	3

I) NBAR

Class	No. of Flows
skype	7

C.2.19 Skype (file transfer)

A) PACE

Class	No. of Flows
Skype:unknown:not_detected	6

B) OpenDPI

Class	No. of Flows
UNKNOWN	6

C) L7-filter-all

Class	No. of Flows
UNKNOWN	5
SKYPE_SUBTYPE_AUDIO	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	6

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	6

F) L7-filter-com

Class	No. of Flows
UNKNOWN	5
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
skype	6

H) Libprotoident

Class	No. of Flows
Unknown_UDP	5
Skype	1

I) NBAR

Class	No. of Flows
skype	6

C.2.20 Skype (video)

A) PACE

Class	No. of Flows
Skype:unknown:not_detected	7

B) OpenDPI

Class	No. of Flows
UNKNOWN	7

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	7

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	7

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_AUDIO	7

G) NDPI

Class	No. of Flows
skype	7

H) Libprotoident

Class	No. of Flows
Skype	6
Unknown_UDP	1

I) NBAR

Class	No. of Flows
skype	7

C.2.21 Sopcast

A) PACE

Class	No. of Flows
SOPCAST:no_subprotocols:not_detected	281
HTTP:generic:not_detected	113
Yahoo:webmail:not_detected	12
FLASH:no_subprotocols:not_detected	10
HTTP:generic:not_yet_detected	4
unknown:no_subprotocols:not_yet_detected	3
SSL:generic:facebook	1

B) OpenDPI

Class	No. of Flows
SOPCAST	281
HTTP	129
FLASH	10
UNKNOWN	3
SSL	1

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	291
FINGER	103
XUNLEI	19
TSP	6
UNKNOWN	4
SKYPE_SUBTYPE_AUDIO	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	399
XUNLEI	19
HTTP_SUBTYPE_UNKNOWN	5
HTTP_SUBTYPE_CHACHEMISS	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	418
HTTP_SUBTYPE_UNKNOWN	5
HTTP_SUBTYPE_CHACHEMISS	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	291
UNKNOWN	101
XUNLEI	19
TSP	6
HTTP_SUBTYPE_UNKNOWN	5
HTTP_SUBTYPE_CHACHEMISS	1
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
sopcast	281
http	121
google	18
skype	4

H) Libprotoident

Class	No. of Flows
Sopcast	198
HTTP	139
Unknown_UDP	82
Unknown_TCP	3
HTTPS	1
Skype	1

I) NBAR

Class	No. of Flows
unclassified	284
http	139
secure-http	1

C.2.22 Spotify

A) PACE

Class	No. of Flows
Spotify:no_subprotocols:not_detected	63
HTTP:generic:not_detected	56
unknown:no_subprotocols:not_yet_detected	42
SSL:generic:amazon_cloud	6
Spotify:no_subprotocols:amazon_cloud	4
HTTP:generic:facebook	3
SSL:generic:not_detected	2
HTTP:generic:not_yet_detected	1
SSL:generic:facebook	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	105
HTTP	64
SSL	9

C) L7-filter-all

Class	No. of Flows
UNKNOWN	95
FINGER	59
SKYPE_SUBTYPE_SKYPEOUT	8
SSL_SUBTYPE_UNKOWN	6
NTP	5
XUNLEI	1
EDONKEY_SUBTYPE_PLAIN	1
KUGOO	1
RTP	1
TSP	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	166
SSL_SUBTYPE_UNKOWN	6
HTTP_SUBTYPE_UNKNOWN	3
HTTP_SUBTYPE_CACHEHIT	1
KUGOO	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	165
SSL_SUBTYPE_UNKOWN	6
FACEBOOK	3
HTTP_SUBTYPE_UNKNOWN	3
HTTP_SUBTYPE_CACHEHIT	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	150
SKYPE_SUBTYPE_SKYPEOUT	8
SSL_SUBTYPE_UNKOWN	6
NTP	5
HTTP_SUBTYPE_UNKNOWN	3
TSP	1
XUNLEI	1
EDONKEY_SUBTYPE_PLAIN	1
HTTP_SUBTYPE_CACHEHIT	1
KUGOO	1
RTP	1

G) NDPI

Class	No. of Flows
skype	85
http	64
unknown	22
ssl_no_cert	6
Spotify	1

H) Libprotoident

Class	No. of Flows
Unknown_TCP	100
HTTP	64
HTTPS	9
No_Payload	4
Spotify	1

I) NBAR

Class	No. of Flows
unclassified	104
http	64
secure-http	9
h323	1

C.2.23 Steam

A) PACE

Class	No. of Flows
Steam:no_subprotocols:not_detected	665
unknown:no_subprotocols:not_yet_detected	530
SSL:generic:windows_azure	6
SSL:generic:amazon_cloud	3
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
UNKNOWN	916
HTTP	279
SSL	6
STEAM	4

C) L7-filter-all

Class	No. of Flows
FINGER	744
UNKNOWN	408
SKYPE_SUBTYPE_SKYPEOUT	48
HTTP_SUBTYPE_UNKNOWN	2
NTP	2
SSL_SUBTYPE_UNKOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1023
HTTP_SUBTYPE_UNKNOWN	181
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1023
HTTP_SUBTYPE_UNKNOWN	181
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	978
HTTP_SUBTYPE_UNKNOWN	169
SKYPE_SUBTYPE_SKYPEOUT	55
NTP	2
SSL_SUBTYPE_UNKOWN	1

G) NDPI

Class	No. of Flows
skype	528
unknown	391
http	279
ssl_no_cert	4
steam	3

H) Libprotoident

Class	No. of Flows
Steam_Friends	505
Steam_UDP	405
HTTP	279
HTTPS	10
Steam_TCP	4
Unknown_TCP	2

I) NBAR

Class	No. of Flows
unclassified	910
http	279
secure-http	9
rtp	6
h323	1

C.2.24 TOR

A) PACE

Class	No. of Flows
TOR:no_subprotocols:not_detected	159
SSL:generic:not_detected	20
DNS:no_subprotocols:not_detected	6

B) OpenDPI

Class	No. of Flows
SSL	179
DNS	6

C) L7-filter-all

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	5
DNS	1

D) L7-filter-sel

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	5
DNS	1

E) L7-filter-aut

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	5
DNS	1

F) L7-filter-com

Class	No. of Flows
SSL_SUBTYPE_UNKOWN	179
UNKNOWN	5
DNS	1

G) NDPI

Class	No. of Flows
skype	160
ssl_no_cert	13
Tor	6
dns	6

H) Libprotoident

Class	No. of Flows
HTTPS	91
TOR	62
SSL/TLS	26
Unknown_UDP	4
DNS	2

I) NBAR

Class	No. of Flows
secure-http	87
unclassified	84
dns	6
http	4
pptp	2
h323	1
pop3	1

C.2.25 World of Warcraft

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	16
World of Warcraft:no_subprotocols:not_detected	6

B) OpenDPI

Class	No. of Flows
HTTP	19
UNKNOWN	3

C) L7-filter-all

Class	No. of Flows
FINGER	14
SKYPE_SUBTYPE_SKYPEOUT	5
UNKNOWN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	14
HTTP_SUBTYPE_UNKNOWN	8

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	14
HTTP_SUBTYPE_UNKNOWN	8

F) L7-filter-com

Class	No. of Flows
UNKNOWN	12
HTTP_SUBTYPE_UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	5

G) NDPI

Class	No. of Flows
http	18
worldofwarcraft	3
google	1

H) Libprotoident

Class	No. of Flows
HTTP	19
WorldOfWarcraft	3

I) NBAR

Class	No. of Flows
http	19
unclassified	3

C.3 Web Services

C.3.1 4Shared

A) PACE

Class	No. of Flows
DirectDownloadLink:4shared.com:not_detected	83
unknown:no_subprotocols:not_yet_detected	11
SSL:generic:not_detected	4

B) OpenDPI

Class	No. of Flows
DIRECT_DOWNLOAD_LINK	82
UNKNOWN	11
SSL	4
HTTP	1

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	64
FINGER	19
UNKNOWN	8
HTTP_SUBTYPE_UNKNOWN	4
SSL_SUBTYPE_UNKOWN	3

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	84
HTTP_SUBTYPE_UNKNOWN	11
SSL_SUBTYPE_UNKOWN	3

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	84
HTTP_SUBTYPE_UNKNOWN	11
SSL_SUBTYPE_UNKOWN	3

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	64
UNKNOWN	27
HTTP_SUBTYPE_UNKNOWN	4
SSL_SUBTYPE_UNKOWN	3

G) NDPI

Class	No. of Flows
http	86
unknown	7
skype	4
http_connect	1

H) Libprotoident

Class	No. of Flows
HTTP	87
No_Payload	7
HTTPS	4

I) NBAR

Class	No. of Flows
http	87
unclassified	7
secure-http	4

C.3.2 Amazon

A) PACE

Class	No. of Flows
HTTP:generic:amazon_cloud	152
HTTP:generic:not_detected	147
SSL:generic:amazon_cloud	145
unknown:no_subprotocols:not_yet_detected	89
HTTP:generic:amazon_shop	57
HTTP:generic:not_yet_detected	9
SSL:generic:not_yet_detected	2
unknown:no_subprotocols:amazon_cloud	1

B) OpenDPI

Class	No. of Flows
HTTP	365
SSL	142
UNKNOWN	95

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	236
FINGER	178
UNKNOWN	171
XUNLEI	8
SSL_SUBTYPE_UNKOWN	6
HTTP_SUBTYPE_UNKNOWN	2
SSL_SUBTYPE_VALIDCERTSSL	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	478
HTTP_SUBTYPE_UNKNOWN	89
HTTP_SUBTYPE_CACHEHIT	19
XUNLEI	8
SSL_SUBTYPE_UNKOWN	6
HTTP_SUBTYPE_CHACHEMISS	1
SSL_SUBTYPE_VALIDCERTSSL	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	483
HTTP_SUBTYPE_UNKNOWN	92
HTTP_SUBTYPE_CACHEHIT	19
SSL_SUBTYPE_UNKOWN	6
HTTP_SUBTYPE_CHACHEMISS	1
SSL_SUBTYPE_VALIDCERTSSL	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	289
SKYPE_SUBTYPE_SKYPEOUT	236
HTTP_SUBTYPE_UNKNOWN	62
XUNLEI	8
SSL_SUBTYPE_UNKOWN	6
SSL_SUBTYPE_VALIDCERTSSL	1

G) NDPI

Class	No. of Flows
http	365
ssl_no_cert	136
unknown	90
ssl	11

H) Libprotoident

Class	No. of Flows
HTTP	360
HTTPS	148
No_Payload	89
BitTorrent	5

I) NBAR

Class	No. of Flows
http	365
secure-http	148
unclassified	89

C.3.3 Apple

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	353
unknown:no_subprotocols:not_yet_detected	94
SSL:generic:facebook	19
HTTP:generic:not_yet_detected	5
HTTP:generic:itunes	2
QUICKTIME:no_subprotocols:itunes	2
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	360
UNKNOWN	96
SSL	19
QUICKTIME	2

C) L7-filter-all

Class	No. of Flows
FINGER	332
UNKNOWN	79
SKYPE_SUBTYPE_SKYPEOUT	28
SSL_SUBTYPE_UNKOWN	21
HTTP_SUBTYPE_UNKNOWN	15
ITUNES	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	403
HTTP_SUBTYPE_UNKNOWN	51
SSL_SUBTYPE_UNKOWN	21
ITUNES	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	403
HTTP_SUBTYPE_UNKNOWN	51
SSL_SUBTYPE_UNKOWN	21
ITUNES	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	378
HTTP_SUBTYPE_UNKNOWN	48
SKYPE_SUBTYPE_SKYPEOUT	28
SSL_SUBTYPE_UNKOWN	21
ITUNES	2

G) NDPI

Class	No. of Flows
http	366
unknown	79
ssl	19
Apple	12
skype	1

H) Libprotoident

Class	No. of Flows
HTTP	377
No_Payload	79
HTTPS	21

I) NBAR

Class	No. of Flows
http	377
unclassified	79
secure-http	21

C.3.4 Ask

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	169
unknown:no_subprotocols:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	169
UNKNOWN	2

C) L7-filter-all

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	96
FINGER	73
UNKNOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	170
HTTP_SUBTYPE_UNKNOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	170
HTTP_SUBTYPE_UNKNOWN	1

F) L7-filter-com

Class	No. of Flows
SKYPE_SUBTYPE_SKYPEOUT	96
UNKNOWN	74
HTTP_SUBTYPE_UNKNOWN	1

G) NDPI

Class	No. of Flows
http	169
unknown	2

H) Libprotoident

Class	No. of Flows
HTTP	169
No_Payload	2

I) NBAR

Class	No. of Flows
http	169
unclassified	2

C.3.5 Bing

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	414
unknown:no_subprotocols:not_yet_detected	25
HTTP:generic:not_yet_detected	15
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	429
UNKNOWN	25
SSL	2

C) L7-filter-all

Class	No. of Flows
FINGER	425
UNKNOWN	23
SKYPE_SUBTYPE_SKYPEOUT	4
HTTP_SUBTYPE_UNKNOWN	2
SSL_SUBTYPE_UNKOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	288
HTTP_SUBTYPE_UNKNOWN	166
SSL_SUBTYPE_UNKOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	288
HTTP_SUBTYPE_UNKNOWN	166
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	286
HTTP_SUBTYPE_UNKNOWN	164
SKYPE_SUBTYPE_SKYPEOUT	4
SSL_SUBTYPE_UNKOWN	2

G) NDPI

Class	No. of Flows
http	431
unknown	23
ssl_no_cert	2

H) Libprotoident

Class	No. of Flows
HTTP	431
No_Payload	23
HTTPS	2

I) NBAR

Class	No. of Flows
http	431
unclassified	23
secure-http	2

C.3.6 Blogspot

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	204
unknown:no_subprotocols:not_yet_detected	18
Google:encrypted:not_detected	9
HTTP:generic:not_yet_detected	2
SPDY:ssl:not_detected	1
SSL:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	206
UNKNOWN	26
SSL	3

C) L7-filter-all

Class	No. of Flows
FINGER	199
UNKNOWN	18
SSL_SUBTYPE_UNKOWN	11
SKYPE_SUBTYPE_SKYPEOUT	7

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	192
UNKNOWN	31
SSL_SUBTYPE_UNKOWN	11
SOCKS	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	192
UNKNOWN	31
SSL_SUBTYPE_UNKOWN	11
SOCKS	1

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	187
UNKNOWN	30
SSL_SUBTYPE_UNKOWN	11
SKYPE_SUBTYPE_SKYPEOUT	7

G) NDPI

Class	No. of Flows
google	219
http	11
skype	4
unknown	1

H) Libprotoident

Class	No. of Flows
HTTP	206
No_Payload	18
HTTPS	11

I) NBAR

Class	No. of Flows
http	205
unclassified	19
secure-http	11

C.3.7 CNN

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	181
HTTP:generic:not_yet_detected	41
unknown:no_subprotocols:not_yet_detected	24
SSL:generic:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	222
UNKNOWN	24
SSL	1

C) L7-filter-all

Class	No. of Flows
FINGER	216
UNKNOWN	25
SKYPE_SUBTYPE_SKYPEOUT	5
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	185
HTTP_SUBTYPE_UNKNOWN	61
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	186
HTTP_SUBTYPE_UNKNOWN	61

F) L7-filter-com

Class	No. of Flows
UNKNOWN	182
HTTP_SUBTYPE_UNKNOWN	59
SKYPE_SUBTYPE_SKYPEOUT	5
XUNLEI	1

G) NDPI

Class	No. of Flows
http	197
skype	26
unknown	24

H) Libprotoident

Class	No. of Flows
HTTP	222
No_Payload	24
HTTPS	1

I) NBAR

Class	No. of Flows
http	222
unclassified	24
secure-http	1

C.3.8 Craigslist

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	162
unknown:no_subprotocols:not_yet_detected	15
HTTP:generic:not_yet_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	164
UNKNOWN	15

C) L7-filter-all

Class	No. of Flows
FINGER	161
UNKNOWN	15
SKYPE_SUBTYPE_SKYPEOUT	3

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	163
UNKNOWN	16

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	163
UNKNOWN	16

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	160
UNKNOWN	16
SKYPE_SUBTYPE_SKYPEOUT	3

G) NDPI

Class	No. of Flows
http	164
unknown	15

H) Libprotoident

Class	No. of Flows
HTTP	164
No_Payload	15

I) NBAR

Class	No. of Flows
http	164
unclassified	15

C.3.9 Cyworld

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	234
unknown:no_subprotocols:not_yet_detected	80
HTTP:generic:not_yet_detected	13
FLASH:no_subprotocols:not_yet_detected	3
FLASH:no_subprotocols:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	247
UNKNOWN	80
FLASH	5

C) L7-filter-all

Class	No. of Flows
FINGER	171
SKYPE_SUBTYPE_SKYPEOUT	90
UNKNOWN	67
KUGOO	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	249
HTTP_SUBTYPE_UNKNOWN	79
KUGOO	4

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	253
HTTP_SUBTYPE_UNKNOWN	79

F) L7-filter-com

Class	No. of Flows
UNKNOWN	194
SKYPE_SUBTYPE_SKYPEOUT	90
HTTP_SUBTYPE_UNKNOWN	44
KUGOO	4

G) NDPI

Class	No. of Flows
http	249
unknown	57
skype	23
flash	3

H) Libprotoident

Class	No. of Flows
HTTP	272
No_Payload	57
RTMP	3

I) NBAR

Class	No. of Flows
http	272
unclassified	60

C.3.10 Doubleclick

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	1447
unknown:no_subprotocols:not_yet_detected	273
HTTP:generic:not_yet_detected	144
MEEBO:unknown:not_detected	52
WINDOWSMEDIA:no_subprotocols:windowsmedia	28
SPDY:ssl:not_detected	21
SSL:generic:not_detected	19
HTTP:video:not_detected	3
FLASH:no_subprotocols:not_detected	1
WINDOWSMEDIA:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	1643
UNKNOWN	285
WINDOWSMEDIA	32
SSL	28
FLASH	1

C) L7-filter-all

Class	No. of Flows
FINGER	1485
UNKNOWN	272
SKYPE_SUBTYPE_SKYPEOUT	191
SSL_SUBTYPE_VALIDCERTSSL	21
SSL_SUBTYPE_UNKOWN	15
SKYPE_SUBTYPE_AUDIO	4
HTTP_SUBTYPE_UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1535
UNKNOWN	386
HTTP_SUBTYPE_VIDEO	28
SSL_SUBTYPE_VALIDCERTSSL	21
SSL_SUBTYPE_UNKOWN	19

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1535
UNKNOWN	386
HTTP_SUBTYPE_VIDEO	28
SSL_SUBTYPE_VALIDCERTSSL	21
SSL_SUBTYPE_UNKOWN	19

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1358
UNKNOWN	372
SKYPE_SUBTYPE_SKYPEOUT	191
HTTP_SUBTYPE_VIDEO	28
SSL_SUBTYPE_VALIDCERTSSL	21
SSL_SUBTYPE_UNKOWN	15
SKYPE_SUBTYPE_AUDIO	4

G) NDPI

Class	No. of Flows
google	1892
http	66
unknown	23
skype	6
ssl_no_cert	2

H) Libprotoident

Class	No. of Flows
HTTP	1676
No_Payload	272
HTTPS	40
BitTorrent	1

I) NBAR

Class	No. of Flows
http	1678
unclassified	271
secure-http	40

C.3.11 eBay

A) PACE

Class	No. of Flows
HTTP:generic:ebay	189
unknown:no_subprotocols:not_yet_detected	77
HTTP:generic:not_detected	8
SSL:generic:not_yet_detected	3
SSL:generic:ebay	2
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	197
UNKNOWN	77
SSL	7

C) L7-filter-all

Class	No. of Flows
FINGER	193
UNKNOWN	79
SSL_SUBTYPE_UNKOWN	5
SKYPE_SUBTYPE_SKYPEOUT	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	148
HTTP_SUBTYPE_UNKNOWN	128
SSL_SUBTYPE_UNKOWN	5

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	148
HTTP_SUBTYPE_UNKNOWN	128
SSL_SUBTYPE_UNKOWN	5

F) L7-filter-com

Class	No. of Flows
UNKNOWN	148
HTTP_SUBTYPE_UNKNOWN	124
SSL_SUBTYPE_UNKOWN	5
SKYPE_SUBTYPE_SKYPEOUT	4

G) NDPI

Class	No. of Flows
http	197
unknown	77
ssl	5
ssl_no_cert	2

H) Libprotoident

Class	No. of Flows
HTTP	197
No_Payload	77
HTTPS	7

I) NBAR

Class	No. of Flows
http	197
unclassified	77
secure-http	7

C.3.12 Facebook

A) PACE

Class	No. of Flows
HTTP:generic:facebook	5419
unknown:no_subprotocols:not_yet_detected	1209
SSL:generic:facebook	109
SPDY:ssl:facebook	73
HTTP:generic:not_yet_detected	60
HTTP:generic:not_detected	57
MPEG:no_subprotocols:facebook	9
FLASH:no_subprotocols:facebook	7
SSL:generic:not_detected	7
SSL:generic:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
HTTP	5538
UNKNOWN	1243
SSL	156
QUICKTIME	8
FLASH	7
MPEG	1

C) L7-filter-all

Class	No. of Flows
FINGER	4897
UNKNOWN	1153
SKYPE_SUBTYPE_SKYPEOUT	417
HTTP_SUBTYPE_UNKNOWN	324
SSL_SUBTYPE_UNKOWN	121
SKYPE_SUBTYPE_AUDIO	39
SSL_SUBTYPE_VALIDCERTSSL	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	6220
HTTP_SUBTYPE_UNKNOWN	570
SSL_SUBTYPE_UNKOWN	160
SSL_SUBTYPE_VALIDCERTSSL	2
PPLIVE	1

E) L7-filter-aut

Class	No. of Flows
FACEBOOK	5435
UNKNOWN	1256
SSL_SUBTYPE_UNKOWN	160
HTTP_SUBTYPE_UNKNOWN	100
SSL_SUBTYPE_VALIDCERTSSL	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	5821
HTTP_SUBTYPE_UNKNOWN	552
SKYPE_SUBTYPE_SKYPEOUT	417
SSL_SUBTYPE_UNKOWN	121
SKYPE_SUBTYPE_AUDIO	39
SSL_SUBTYPE_VALIDCERTSSL	2
PPLIVE	1

G) NDPI

Class	No. of Flows
http	5051
unknown	1237
facebook	589
skype	29
ssl	24
ssl_no_cert	23

H) Libprotoident

Class	No. of Flows
HTTP	5637
No_Payload	1123
HTTPS	192
BitTorrent	1

I) NBAR

Class	No. of Flows
http	5614
unclassified	1147
secure-http	192

C.3.13 Go.com

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	202
unknown:no_subprotocols:not_yet_detected	70
HTTP:generic:not_yet_detected	49
SSL:generic:not_detected	8
FLASH:no_subprotocols:not_detected	6

B) OpenDPI

Class	No. of Flows
HTTP	251
UNKNOWN	78
FLASH	6

C) L7-filter-all

Class	No. of Flows
FINGER	219
UNKNOWN	43
SKYPE_SUBTYPE_SKYPEOUT	37
HTTP_SUBTYPE_UNKNOWN	27
SSL_SUBTYPE_UNKOWN	8
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	177
HTTP_SUBTYPE_UNKNOWN	141
SSL_SUBTYPE_UNKOWN	8
HTTP_SUBTYPE_CACHEHIT	7
HTTP_SUBTYPE_CHACHEMISS	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	177
HTTP_SUBTYPE_UNKNOWN	142
SSL_SUBTYPE_UNKOWN	8
HTTP_SUBTYPE_CACHEHIT	7
HTTP_SUBTYPE_CHACHEMISS	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	151
HTTP_SUBTYPE_UNKNOWN	130
SKYPE_SUBTYPE_SKYPEOUT	37
SSL_SUBTYPE_UNKOWN	8
HTTP_SUBTYPE_CACHEHIT	7
HTTP_SUBTYPE_CHACHEMISS	1
XUNLEI	1

G) NDPI

Class	No. of Flows
http	284
unknown	43
skype	8

H) Libprotoident

Class	No. of Flows
HTTP	284
No_Payload	43
HTTPS	8

I) NBAR

Class	No. of Flows
http	281
unclassified	43
secure-http	8
h323	3

C.3.14 Google

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	3539
unknown:no_subprotocols:not_yet_detected	900
Google:encrypted:not_detected	672
HTTP:media:not_detected	495
SSL:generic:not_detected	453
HTTP:generic:not_yet_detected	259
SPDY:ssl:not_detected	134
FLASH:no_subprotocols:not_detected	52
Google:plus:not_detected	8
HTTP:generic:gmail	7
Google:encrypted:not_yet_detected	6
SSL:generic:gmail	6
SSL:generic:not_yet_detected	3
Google:drive:not_detected	2
Google:plus:not_yet_detected	2
SPDY:ssl:gmail	2
Google:docs:googledocs	1

B) OpenDPI

Class	No. of Flows
HTTP	4300
UNKNOWN	1184
SSL	1003
FLASH	54

C) L7-filter-all

Class	No. of Flows
FINGER	2794
SKYPE_SUBTYPE_SKYPEOUT	1094
SSL_SUBTYPE_UNKOWN	985
UNKNOWN	914
HTTP_SUBTYPE_UNKNOWN	462
SSL_SUBTYPE_VALIDCERTSSL	232
SKYPE_SUBTYPE_AUDIO	54
ARMAGETRON	3
DNS	2
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	3660
UNKNOWN	1604
SSL_SUBTYPE_UNKOWN	1038
SSL_SUBTYPE_VALIDCERTSSL	232
ARMAGETRON	3
DNS	2
HTTP_SUBTYPE_VIDEO	1
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	3661
UNKNOWN	1604
SSL_SUBTYPE_UNKOWN	1038
SSL_SUBTYPE_VALIDCERTSSL	232
ARMAGETRON	3
DNS	2
HTTP_SUBTYPE_VIDEO	1

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	2747
UNKNOWN	1422
SKYPE_SUBTYPE_SKYPEOUT	1094
SSL_SUBTYPE_UNKOWN	985
SSL_SUBTYPE_VALIDCERTSSL	232
SKYPE_SUBTYPE_AUDIO	54
ARMAGETRON	3
DNS	2
HTTP_SUBTYPE_VIDEO	1
XUNLEI	1

G) NDPI

Class	No. of Flows
google	5047
http	1023
unknown	246
skype	165
ssl_no_cert	55
ssl	5

H) Libprotoident

Class	No. of Flows
HTTP	4352
HTTPS	1292
No_Payload	892
BitTorrent	5

I) NBAR

Class	No. of Flows
http	4363
secure-http	1291
unclassified	887

C.3.15 Instagram

A) PACE

Class	No. of Flows
HTTP:generic:instagram	8
unknown:no_subprotocols:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	8
UNKNOWN	1

C) L7-filter-all

Class	No. of Flows
FINGER	7
SKYPE_SUBTYPE_SKYPEOUT	1
UNKNOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	8
HTTP_SUBTYPE_UNKNOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	8
HTTP_SUBTYPE_UNKNOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	7
SKYPE_SUBTYPE_SKYPEOUT	1
HTTP_SUBTYPE_UNKNOWN	1

G) NDPI

Class	No. of Flows
http	8
unknown	1

H) Libprotoident

Class	No. of Flows
HTTP	8
No_Payload	1

I) NBAR

Class	No. of Flows
http	8
unclassified	1

C.3.16 Justin.tv

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	1788
unknown:no_subprotocols:not_yet_detected	294
FLASH:no_subprotocols:not_detected	145
HTTP:generic:not_yet_detected	99

B) OpenDPI

Class	No. of Flows
HTTP	1887
UNKNOWN	294
FLASH	145

C) L7-filter-all

Class	No. of Flows
FINGER	1445
XUNLEI	474
UNKNOWN	278
SKYPE_SUBTYPE_SKYPEOUT	110
HTTP_SUBTYPE_UNKNOWN	19

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	1252
HTTP_SUBTYPE_UNKNOWN	600
XUNLEI	474

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	1487
HTTP_SUBTYPE_UNKNOWN	839

F) L7-filter-com

Class	No. of Flows
UNKNOWN	1198
HTTP_SUBTYPE_UNKNOWN	543
XUNLEI	474
SKYPE_SUBTYPE_SKYPEOUT	110
SKYPE_SUBTYPE_AUDIO	1

G) NDPI

Class	No. of Flows
http	2049
unknown	277

H) Libprotoident

Class	No. of Flows
HTTP	1963
No_Payload	278
HTTP_NonStandard	77
BitTorrent	7
HTTP_443	1

I) NBAR

Class	No. of Flows
http	1975
unclassified	284
secure-http	67

C.3.17 LinkedIn

A) PACE

Class	No. of Flows
HTTP:generic:linkedin	30
SSL:generic:linkedin	18
unknown:no_subprotocols:not_yet_detected	14

B) OpenDPI

Class	No. of Flows
HTTP	29
SSL	18
UNKNOWN	15

C) L7-filter-all

Class	No. of Flows
FINGER	28
SSL_SUBTYPE_UNKOWN	18
UNKNOWN	9
HTTP_SUBTYPE_UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	29
SSL_SUBTYPE_UNKOWN	18
HTTP_SUBTYPE_UNKNOWN	15

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	29
SSL_SUBTYPE_UNKOWN	18
HTTP_SUBTYPE_UNKNOWN	15

F) L7-filter-com

Class	No. of Flows
UNKNOWN	27
SSL_SUBTYPE_UNKOWN	18
HTTP_SUBTYPE_UNKNOWN	15
SKYPE_SUBTYPE_SKYPEOUT	2

G) NDPI

Class	No. of Flows
http	32
skype	21
unknown	9

H) Libprotoident

Class	No. of Flows
HTTP	35
HTTPS	18
No_Payload	9

I) NBAR

Class	No. of Flows
http	35
secure-http	18
unclassified	9

C.3.18 Mediafire

A) PACE

Class	No. of Flows
SSL:generic:not_detected	326
DirectDownloadLink:mediafire.com:not_detected	143
unknown:no_subprotocols:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
UNKNOWN	329
DIRECT_DOWNLOAD_LINK	143

C) L7-filter-all

Class	No. of Flows
UNKNOWN	328
FINGER	121
SKYPE_SUBTYPE_SKYPEOUT	20
HTTP_SUBTYPE_UNKNOWN	2
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	469
HTTP_SUBTYPE_UNKNOWN	2
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	470
HTTP_SUBTYPE_UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	449
SKYPE_SUBTYPE_SKYPEOUT	20
HTTP_SUBTYPE_UNKNOWN	2
XUNLEI	1

G) NDPI

Class	No. of Flows
skype	326
http	144
unknown	2

H) Libprotoident

Class	No. of Flows
HTTPS	326
HTTP	144
No_Payload	2

I) NBAR

Class	No. of Flows
secure-http	326
http	144
unclassified	2

C.3.19 MSN

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	649
unknown:no_subprotocols:not_yet_detected	226
HTTP:generic:not_yet_detected	45
QUICKTIME:no_subprotocols:not_detected	3
SSL:generic:not_detected	3
FLASH:no_subprotocols:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	694
UNKNOWN	226
QUICKTIME	3
SSL	3
FLASH	2

C) L7-filter-all

Class	No. of Flows
FINGER	593
UNKNOWN	223
SKYPE_SUBTYPE_SKYPEOUT	106
HTTP_SUBTYPE_UNKNOWN	3
SOCKS	2
SSL_SUBTYPE_UNKOWN	1

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	722
HTTP_SUBTYPE_UNKNOWN	198
HTTP_SUBTYPE_VIDEO	4
SOCKS	2
NBNS	1
SSL_SUBTYPE_UNKOWN	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	722
HTTP_SUBTYPE_UNKNOWN	198
HTTP_SUBTYPE_VIDEO	4
SOCKS	2
NBNS	1
SSL_SUBTYPE_UNKOWN	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	657
HTTP_SUBTYPE_UNKNOWN	157
SKYPE_SUBTYPE_SKYPEOUT	106
HTTP_SUBTYPE_VIDEO	4
SOCKS	2
NBNS	1
SSL_SUBTYPE_UNKOWN	1

G) NDPI

Class	No. of Flows
http	670
unknown	213
skype	42
ssl_no_cert	3

H) Libprotoident

Class	No. of Flows
HTTP	700
No_Payload	223
HTTPS	3
BitTorrent	2

I) NBAR

Class	No. of Flows
http	702
unclassified	223
secure-http	3

C.3.20 MySpace

A) PACE

Class	No. of Flows
HTTP:generic:myspace	2

B) OpenDPI

Class	No. of Flows
HTTP	2

C) L7-filter-all

Class	No. of Flows
FINGER	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	2

G) NDPI

Class	No. of Flows
http	2

H) Libprotoident

Class	No. of Flows
HTTP	2

I) NBAR

Class	No. of Flows
http	2

C.3.21 Pinterest

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	133
unknown:no_subprotocols:not_yet_detected	25
HTTP:generic:not_yet_detected	24
SSL:generic:not_detected	7

B) OpenDPI

Class	No. of Flows
HTTP	157
UNKNOWN	30
SSL	2

C) L7-filter-all

Class	No. of Flows
FINGER	116
SKYPE_SUBTYPE_SKYPEOUT	35
UNKNOWN	28
XUNLEI	5
HTTP_SUBTYPE_UNKNOWN	3
SSL_SUBTYPE_UNKOWN	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	126
HTTP_SUBTYPE_CACHEHIT	29
HTTP_SUBTYPE_UNKNOWN	23
XUNLEI	5
HTTP_SUBTYPE_CHACHEMISS	4
SSL_SUBTYPE_UNKOWN	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	128
HTTP_SUBTYPE_CACHEHIT	29
HTTP_SUBTYPE_UNKNOWN	26
HTTP_SUBTYPE_CHACHEMISS	4
SSL_SUBTYPE_UNKOWN	2

F) L7-filter-com

Class	No. of Flows
UNKNOWN	96
SKYPE_SUBTYPE_SKYPEOUT	35
HTTP_SUBTYPE_CACHEHIT	27
HTTP_SUBTYPE_UNKNOWN	20
XUNLEI	5
HTTP_SUBTYPE_CHACHEMISS	4
SSL_SUBTYPE_UNKOWN	2

G) NDPI

Class	No. of Flows
http	159
unknown	23
skype	7

H) Libprotoident

Class	No. of Flows
HTTP	159
No_Payload	23
HTTPS	7

I) NBAR

Class	No. of Flows
http	159
unclassified	23
secure-http	7

C.3.22 Putlocker

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	76
unknown:no_subprotocols:not_yet_detected	13
HTTP:generic:not_yet_detected	11
SSL:generic:not_detected	2
FLASH:no_subprotocols:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	87
UNKNOWN	15
FLASH	1

C) L7-filter-all

Class	No. of Flows
FINGER	41
SKYPE_SUBTYPE_SKYPEOUT	33
UNKNOWN	14
HTTP_SUBTYPE_UNKNOWN	13
XUNLEI	2

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	86
HTTP_SUBTYPE_UNKNOWN	15
XUNLEI	2

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	88
HTTP_SUBTYPE_UNKNOWN	15

F) L7-filter-com

Class	No. of Flows
UNKNOWN	53
SKYPE_SUBTYPE_SKYPEOUT	33
HTTP_SUBTYPE_UNKNOWN	15
XUNLEI	2

G) NDPI

Class	No. of Flows
http	89
unknown	12
skype	2

H) Libprotoident

Class	No. of Flows
HTTP	89
No_Payload	12
HTTPS	2

I) NBAR

Class	No. of Flows
http	64
unclassified	23
secure-http	16

C.3.23 QQ.com

A) PACE

Class	No. of Flows
QQLive:no_subprotocols:not_detected	242
HTTP:generic:not_yet_detected	193
HTTP:generic:not_detected	180
unknown:no_subprotocols:not_yet_detected	135
FLASH:no_subprotocols:not_detected	3

B) OpenDPI

Class	No. of Flows
HTTP	612
UNKNOWN	136
FLASH	5

C) L7-filter-all

Class	No. of Flows
FINGER	411
HTTP_SUBTYPE_UNKNOWN	142
UNKNOWN	132
SKYPE_SUBTYPE_SKYPEOUT	67
XUNLEI	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	386
UNKNOWN	359
HTTP_SUBTYPE_CACHEHIT	5
HTTP_SUBTYPE_CHACHEMISS	2
XUNLEI	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	387
UNKNOWN	359
HTTP_SUBTYPE_CACHEHIT	5
HTTP_SUBTYPE_CHACHEMISS	2

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	340
UNKNOWN	335
SKYPE_SUBTYPE_SKYPEOUT	70
HTTP_SUBTYPE_CACHEHIT	5
HTTP_SUBTYPE_CHACHEMISS	2
XUNLEI	1

G) NDPI

Class	No. of Flows
http	616
unknown	116
skype	21

H) Libprotoident

Class	No. of Flows
HTTP	620
No_Payload	111
Unknown_TCP	21
BitTorrent	1

I) NBAR

Class	No. of Flows
http	636
unclassified	117

C.3.24 Taobao

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	292
unknown:no_subprotocols:not_yet_detected	71
HTTP:generic:not_yet_detected	22
SSL:generic:not_detected	2

B) OpenDPI

Class	No. of Flows
HTTP	314
UNKNOWN	73

C) L7-filter-all

Class	No. of Flows
FINGER	294
HTTP_SUBTYPE_UNKNOWN	42
UNKNOWN	31
SKYPE_SUBTYPE_SKYPEOUT	20

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	199
HTTP_SUBTYPE_UNKNOWN	188

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	199
HTTP_SUBTYPE_UNKNOWN	188

F) L7-filter-com

Class	No. of Flows
UNKNOWN	196
HTTP_SUBTYPE_UNKNOWN	171
SKYPE_SUBTYPE_SKYPEOUT	20

G) NDPI

Class	No. of Flows
http	356
unknown	29
skype	2

H) Libprotoident

Class	No. of Flows
HTTP	355
No_Payload	29
HTTPS	2
BitTorrent	1

I) NBAR

Class	No. of Flows
http	356
unclassified	29
secure-http	2

C.3.25 The Huffington Post

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	62
HTTP:generic:not_yet_detected	5
unknown:no_subprotocols:not_yet_detected	4

B) OpenDPI

Class	No. of Flows
HTTP	67
UNKNOWN	4

C) L7-filter-all

Class	No. of Flows
FINGER	47
SKYPE_SUBTYPE_SKYPEOUT	18
UNKNOWN	4
XUNLEI	2

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	50
UNKNOWN	19
XUNLEI	2

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	52
UNKNOWN	19

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	39
SKYPE_SUBTYPE_SKYPEOUT	18
UNKNOWN	12
XUNLEI	2

G) NDPI

Class	No. of Flows
http	67
unknown	4

H) Libprotoident

Class	No. of Flows
HTTP	67
No_Payload	4

I) NBAR

Class	No. of Flows
http	67
unclassified	4

C.3.26 Tumblr

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	296
unknown:no_subprotocols:not_yet_detected	76
HTTP:generic:not_yet_detected	20
SSL:generic:not_detected	7
SSL:generic:not_yet_detected	3
SPDY:ssl:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	316
UNKNOWN	76
SSL	11

C) L7-filter-all

Class	No. of Flows
FINGER	272
HTTP_SUBTYPE_UNKNOWN	49
UNKNOWN	36
SKYPE_SUBTYPE_SKYPEOUT	20
HTTP_SUBTYPE_CACHEHIT	11
SSL_SUBTYPE_UNKOWN	10
XUNLEI	4
SSL_SUBTYPE_VALIDCERTSSL	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	188
UNKNOWN	122
HTTP_SUBTYPE_CACHEHIT	74
SSL_SUBTYPE_UNKOWN	10
XUNLEI	4
HTTP_SUBTYPE_CHACHEMISS	3
KUGOO	1
SSL_SUBTYPE_VALIDCERTSSL	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	192
UNKNOWN	123
HTTP_SUBTYPE_CACHEHIT	74
SSL_SUBTYPE_UNKOWN	10
HTTP_SUBTYPE_CHACHEMISS	3
SSL_SUBTYPE_VALIDCERTSSL	1

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	183
UNKNOWN	121
HTTP_SUBTYPE_CACHEHIT	60
SKYPE_SUBTYPE_SKYPEOUT	20
SSL_SUBTYPE_UNKOWN	10
XUNLEI	4
HTTP_SUBTYPE_CHACHEMISS	3
KUGOO	1
SSL_SUBTYPE_VALIDCERTSSL	1

G) NDPI

Class	No. of Flows
http	356
unknown	36
ssl	10
ssl_no_cert	1

H) Libprotoident

Class	No. of Flows
HTTP	356
No_Payload	36
HTTPS	11

I) NBAR

Class	No. of Flows
http	347
unclassified	45
secure-http	11

C.3.27 Twitter

A) PACE

Class	No. of Flows
HTTP:generic:twitter	555
unknown:no_subprotocols:not_yet_detected	325
SSL:generic:twitter	255
HTTP:generic:not_yet_detected	3

B) OpenDPI

Class	No. of Flows
HTTP	558
UNKNOWN	452
SSL	128

C) L7-filter-all

Class	No. of Flows
UNKNOWN	327
FINGER	252
SKYPE_SUBTYPE_SKYPEOUT	177
SSL_SUBTYPE_UNKOWN	140
XUNLEI	128
SSL_SUBTYPE_VALIDCERTSSL	55
SKYPE_SUBTYPE_AUDIO	40
HTTP_SUBTYPE_UNKNOWN	19

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	399
HTTP_SUBTYPE_UNKNOWN	369
SSL_SUBTYPE_UNKOWN	180
XUNLEI	128
SSL_SUBTYPE_VALIDCERTSSL	55
HTTP_SUBTYPE_CACHEHIT	7

E) L7-filter-aut

Class	No. of Flows
TWITTER	554
UNKNOWN	330
SSL_SUBTYPE_UNKOWN	180
SSL_SUBTYPE_VALIDCERTSSL	55
HTTP_SUBTYPE_UNKNOWN	19

F) L7-filter-com

Class	No. of Flows
UNKNOWN	399
HTTP_SUBTYPE_UNKNOWN	192
SKYPE_SUBTYPE_SKYPEOUT	177
SSL_SUBTYPE_UNKOWN	140
XUNLEI	128
SSL_SUBTYPE_VALIDCERTSSL	55
SKYPE_SUBTYPE_AUDIO	40
HTTP_SUBTYPE_CACHEHIT	7

G) NDPI

Class	No. of Flows
http	550
unknown	352
ssl_no_cert	189
twitter	27
skype	15
ssl	5

H) Libprotoident

Class	No. of Flows
HTTP	576
No_Payload	307
HTTPS	255

I) NBAR

Class	No. of Flows
http	578
unclassified	308
secure-http	252

C.3.28 Vimeo

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	49
SSL:generic:not_detected	34
unknown:no_subprotocols:not_yet_detected	21
QUICKTIME:no_subprotocols:not_detected	10
FLASH:no_subprotocols:not_detected	9
SSL:generic:not_yet_detected	6
HTTP:video:not_detected	2

B) OpenDPI

Class	No. of Flows
UNKNOWN	61
HTTP	49
QUICKTIME	12
FLASH	9

C) L7-filter-all

Class	No. of Flows
FINGER	61
SSL_SUBTYPE_UNKOWN	38
UNKNOWN	22
HTTP_SUBTYPE_UNKNOWN	5
SKYPE_SUBTYPE_SKYPEOUT	5

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	74
SSL_SUBTYPE_UNKOWN	38
HTTP_SUBTYPE_UNKNOWN	18
HTTP_SUBTYPE_VIDEO	1

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	74
SSL_SUBTYPE_UNKOWN	38
HTTP_SUBTYPE_UNKNOWN	18
HTTP_SUBTYPE_VIDEO	1

F) L7-filter-com

Class	No. of Flows
UNKNOWN	70
SSL_SUBTYPE_UNKOWN	38
HTTP_SUBTYPE_UNKNOWN	17
SKYPE_SUBTYPE_SKYPEOUT	5
HTTP_SUBTYPE_VIDEO	1

G) NDPI

Class	No. of Flows
http	71
skype	35
unknown	20
ssl_no_cert	5

H) Libprotoident

Class	No. of Flows
HTTP	71
HTTPS	40
No_Payload	20

I) NBAR

Class	No. of Flows
http	71
secure-http	40
unclassified	20

C.3.29 VK.com

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	334
unknown:no_subprotocols:not_yet_detected	9

B) OpenDPI

Class	No. of Flows
HTTP	334
UNKNOWN	9

C) L7-filter-all

Class	No. of Flows
FINGER	322
SKYPE_SUBTYPE_SKYPEOUT	12
UNKNOWN	9

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	202
UNKNOWN	141

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	202
UNKNOWN	141

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	194
UNKNOWN	137
SKYPE_SUBTYPE_SKYPEOUT	12

G) NDPI

Class	No. of Flows
http	334
unknown	9

H) Libprotoident

Class	No. of Flows
HTTP	334
No_Payload	9

I) NBAR

Class	No. of Flows
http	334
unclassified	9

C.3.30 Wikipedia

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	3740
unknown:no_subprotocols:not_yet_detected	1874
HTTP:generic:not_yet_detected	444
SSL:generic:not_detected	22
SSL:generic:not_yet_detected	12

B) OpenDPI

Class	No. of Flows
HTTP	4189
UNKNOWN	1901
SSL	2

C) L7-filter-all

Class	No. of Flows
FINGER	4151
UNKNOWN	1876
SKYPE_SUBTYPE_SKYPEOUT	33
SSL_SUBTYPE_UNKOWN	30
HTTP_SUBTYPE_CACHEHIT	1
SOCKS	1

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_CACHEHIT	2247
UNKNOWN	1918
HTTP_SUBTYPE_UNKNOWN	1863
HTTP_SUBTYPE_CHACHEMISS	33
SSL_SUBTYPE_UNKOWN	30
SOCKS	1

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_CACHEHIT	2247
UNKNOWN	1918
HTTP_SUBTYPE_UNKNOWN	1863
HTTP_SUBTYPE_CHACHEMISS	33
SSL_SUBTYPE_UNKOWN	30
SOCKS	1

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_CACHEHIT	2246
UNKNOWN	1918
HTTP_SUBTYPE_UNKNOWN	1830
SKYPE_SUBTYPE_SKYPEOUT	34
HTTP_SUBTYPE_CHACHEMISS	33
SSL_SUBTYPE_UNKOWN	30
SOCKS	1

G) NDPI

Class	No. of Flows
http	4190
unknown	1868
ssl_no_cert	30
skype	4

H) Libprotoident

Class	No. of Flows
HTTP	4183
No_Payload	1872
HTTPS	35
BitTorrent	2

I) NBAR

Class	No. of Flows
http	4185
unclassified	1872
secure-http	35

C.3.31 Windows Live

A) PACE

Class	No. of Flows
HTTP:generic:hotmail_webmail	12
SSL:generic:live_com	8
HTTP:generic:live_com	5
unknown:no_subprotocols:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	17
SSL	8
UNKNOWN	1

C) L7-filter-all

Class	No. of Flows
FINGER	17
UNKNOWN	9

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	26

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	26

F) L7-filter-com

Class	No. of Flows
UNKNOWN	26

G) NDPI

Class	No. of Flows
http	17
ssl_no_cert	8
unknown	1

H) Libprotoident

Class	No. of Flows
HTTP	17
HTTPS	8
No_Payload	1

I) NBAR

Class	No. of Flows
http	17
secure-http	8
unclassified	1

C.3.32 Wordpress

A) PACE

Class	No. of Flows
HTTP:generic:not_detected	142
unknown:no_subprotocols:not_yet_detected	19
SPDY:ssl:not_detected	7
HTTP:generic:not_yet_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	143
UNKNOWN	26

C) L7-filter-all

Class	No. of Flows
FINGER	129
UNKNOWN	20
SKYPE_SUBTYPE_SKYPEOUT	14
SSL_SUBTYPE_UNKOWN	6

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	91
UNKNOWN	72
SSL_SUBTYPE_UNKOWN	6

E) L7-filter-aut

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	91
UNKNOWN	72
SSL_SUBTYPE_UNKOWN	6

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	77
UNKNOWN	72
SKYPE_SUBTYPE_SKYPEOUT	14
SSL_SUBTYPE_UNKOWN	6

G) NDPI

Class	No. of Flows
http	143
unknown	19
ssl_no_cert	6
skype	1

H) Libprotoident

Class	No. of Flows
HTTP	143
No_Payload	19
HTTPS	7

I) NBAR

Class	No. of Flows
http	143
unclassified	19
secure-http	7

C.3.33 Yahoo

A) PACE

Class	No. of Flows
Yahoo:webmail:not_detected	9452
HTTP:generic:not_detected	4560
unknown:no_subprotocols:not_yet_detected	2746
HTTP:generic:not_yet_detected	333
FLASH:no_subprotocols:not_yet_detected	76
SSL:generic:not_detected	62
FLASH:no_subprotocols:not_detected	61
Yahoo:unknown:not_detected	43
HTTP:generic:ebay	25
HTTP:generic:flickr	5
SSL:generic:not_yet_detected	5
Yahoo:webchat:not_detected	4
HTTP:media:not_detected	1

B) OpenDPI

Class	No. of Flows
HTTP	14464
UNKNOWN	2704
FLASH	138
SSL	67

C) L7-filter-all

Class	No. of Flows
FINGER	13964
UNKNOWN	2411
SKYPE_SUBTYPE_SKYPEOUT	750
HTTP_SUBTYPE_UNKNOWN	176
SSL_SUBTYPE_UNKOWN	53
XUNLEI	9
SKYPE_SUBTYPE_AUDIO	6
TSP	4

D) L7-filter-sel

Class	No. of Flows
UNKNOWN	16122
HTTP_SUBTYPE_UNKNOWN	1183
SSL_SUBTYPE_UNKOWN	59
XUNLEI	9

E) L7-filter-aut

Class	No. of Flows
UNKNOWN	16127
HTTP_SUBTYPE_UNKNOWN	1187
SSL_SUBTYPE_UNKOWN	59

F) L7-filter-com

Class	No. of Flows
UNKNOWN	15388
HTTP_SUBTYPE_UNKNOWN	1163
SKYPE_SUBTYPE_SKYPEOUT	750
SSL_SUBTYPE_UNKOWN	53
XUNLEI	9
SKYPE_SUBTYPE_AUDIO	6
TSP	4

G) NDPI

Class	No. of Flows
http	14361
unknown	2705
yahoo	157
flash	82
ssl_no_cert	46
ssl	17
http_connect	5

H) Libprotoident

Class	No. of Flows
HTTP	14481
No_Payload	2312
YahooError	410
RTMP	81
HTTPS	67
Unknown_TCP	21
Web_Junk	1

I) NBAR

Class	No. of Flows
http	14197
unclassified	3107
secure-http	67
irc	2

C.3.34 YouTube

A) PACE

Class	No. of Flows
HTTP:generic:youtube	1723
unknown:no_subprotocols:not_yet_detected	352
FLASH:no_subprotocols:youtube	264
SPDY:ssl:not_detected	42
Google:encrypted:not_detected	36
HTTP:generic:not_detected	23
HTTP:generic:not_yet_detected	23
HTTP:video:youtube	18
SSL:generic:not_detected	17
Google:plus:not_detected	11
QUICKTIME:no_subprotocols:youtube	9
MPEG:no_subprotocols:youtube	8
WINDOWSMEDIA:no_subprotocols:youtube	4
Google:plus:not_yet_detected	2
Google:encrypted:not_yet_detected	1
HTTP:media:youtube	1

B) OpenDPI

Class	No. of Flows
HTTP	1790
UNKNOWN	357
FLASH	276
SSL	102
QUICKTIME	9

C) L7-filter-all

Class	No. of Flows
FINGER	1881
UNKNOWN	350
SKYPE_SUBTYPE_SKYPEOUT	183
SSL_SUBTYPE_UNKOWN	94
SSL_SUBTYPE_VALIDCERTSSL	9
HTTP_SUBTYPE_UNKNOWN	7
XUNLEI	7
SKYPE_SUBTYPE_AUDIO	3

D) L7-filter-sel

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1440
UNKNOWN	934
SSL_SUBTYPE_UNKOWN	97
HTTP_SUBTYPE_VIDEO	42
SSL_SUBTYPE_VALIDCERTSSL	9
XUNLEI	7
HTTP_SUBTYPE_AUDIO	4
KUGOO	1

E) L7-filter-aut

Class	No. of Flows
YOUTUBE	1551
UNKNOWN	794
SSL_SUBTYPE_UNKOWN	97
HTTP_SUBTYPE_UNKNOWN	66
HTTP_SUBTYPE_VIDEO	13
SSL_SUBTYPE_VALIDCERTSSL	9
HTTP_SUBTYPE_AUDIO	4

F) L7-filter-com

Class	No. of Flows
HTTP_SUBTYPE_UNKNOWN	1331
UNKNOWN	860
SKYPE_SUBTYPE_SKYPEOUT	183
SSL_SUBTYPE_UNKOWN	94
HTTP_SUBTYPE_VIDEO	42
SSL_SUBTYPE_VALIDCERTSSL	9
XUNLEI	7
HTTP_SUBTYPE_AUDIO	4
SKYPE_SUBTYPE_AUDIO	3
KUGOO	1

G) NDPI

Class	No. of Flows
google	1918
http	480
unknown	81
youtube	48
skype	6
ssl_no_cert	1

H) Libprotoident

Class	No. of Flows
HTTP	2077
No_Payload	343
HTTPS	109
BitTorrent	5

I) NBAR

Class	No. of Flows
http	2054
unclassified	371
secure-http	109

Extended Independent Comparison of Popular Deep Packet Inspection (DPI) Tools for Traffic Classification

TOMASZ BUJLOW, VALENTIN CARELA-ESPAÑOL, PERE BARLET-ROS

Network traffic classification became an essential input for many network-related tasks. However, the continuous evolution of the Internet applications and their techniques to avoid being detected considerably complicated their classification. Using our host-based monitoring and packet capturing tool, we created 3 datasets, which contain 767 690 flows representing 17 application protocols, 19 applications, and 34 web services. The datasets are available to the research community. The first dataset contains full flows with entire packets, the second dataset contains truncated packets (the Ethernet frames were overwritten by 0s after the 70th byte), and the third dataset contains truncated flows (we took only 10 first packets for each flow).

Then, we examined the ability of various well-known DPI tools (PACE, OpenDPI, L7-filter, NDPI, Libprotoident, and NBAR) to accurately label the flows included in our datasets. We evaluated the impact of protocol encryption or obfuscation on the detection rate by the particular classifiers. We also show how the packet or flow truncations relate to the classification accuracy by the DPI tools.

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